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A PRACTICAL FRAMEWORK FOR PLANNING PRO-DEVELOPMENT CLIMATE POLICY

United Nations Environment Programme

Contributors

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Climate is an inordinate challenge but also an inordinate opportunity to transform economies onto a low-carbon, resource-efficient Green Economy path.

Catalyzing clean energy will not only cut greenhouse-gas emissions as part of efforts to limit a global temperature rise to under 2 degrees C or more, it also represents a way of curbing health-hazardous air pollution while offering a rapid path to address energy poverty, especially in rural areas of developing economies.

Meanwhile enhancing ecosystems such as forests, mangroves and seagrasses in order to conserve their carbon stocks can also trigger multiple benefits from boosting water supplies and improving agriculture to maintaining natural sea defences and nurseries for fish. The 17th Conference of the Parties meeting in Durban, South Africa, later this year presents the world with another opportunity to advance the climate agenda and co-operative action under the UN Climate Convention.

It is crucial that those actions are designed within a coherent and robust policy-planning framework to ensure that they are both cost-effective and compatible with broader social, economic and environmental goals. For developing countries, sound climate-policy planning will also enhance access to climate finance from the developed ones.

Climate-policy planning is a complex undertaking. Many developing countries are only just starting to consider how to go about it and some require improved access to the requisite knowledge, expertise and technical skills. Drawing upon best practices, tried and tested in other parts of the world, is clearly an advantage. The MCA4climate, a new UNEP initiative, is designed to assist policymakers, particularly in the developing world, in that endeavour. It offers concrete guidance and recommendations on a number of critical issues and proposes a formal framework for evaluating climate mitigation and adaptation policies, paving a practical way forward so that countries evolve sustainably and grow their economies in a way that keeps humanity's footprint within planetary boundaries. It draws on the work of leading experts on climate policymaking from around the world and uses an innovative approach to assessing policies that ensures that climate policies and strategies take full account of developmental concerns and objectives.

The MCA4climate initiative reflects UNEP's mission to provide leadership and encourage partnership in caring for the environment by inspiring, informing and enabling nations and peoples to improve their quality of life without compromising that of future generations—issues at the centre of Rio+20 next year in Brazil as governments look to scale-up and accelerate the implementation of the agreements, including those relating to climate change, established in Rio in 1992.

Achim Steiner,
UN Under-Secretary General and Executive Director
United Nations Environment Programme (UNEP)

At the UN Climate Change Conference in Cancun in December 2010, the countries of the world laid the foundation for the most far-reaching collective effort the world has ever seen to reduce carbon emissions, and to build a system which makes all countries accountable to one another for those emission reductions.

Under the Cancun Agreements, all industrialized nations made official their reduction pledges, and committed themselves to develop low-carbon development plans or strategies. Developing countries made official their nationally appropriate mitigation actions (NAMAs) which seek a deviation from business-as-usual emissions by 2020, and were encouraged to develop low-carbon growth strategies.

In addition, the Cancun Agreements provide the strongest signal countries have ever given to the private sector that we are moving toward low-carbon economies, by committing to a maximum temperature rise of 2 degrees Celsius, and a consideration of a maximum of 1.5 degrees in the near future.

It is clear that the poorer developing countries will need substantial financial and technical support in preparing and implementing mitigation and adaptation actions. The agreements in Cancun on mobilizing finance for developing countries, including the establishment of a Green Climate Fund and a registry to match action with funding and other types of support, constitute major steps forward. So do the agreements on a new Technology Mechanism and Adaptation Committee.

All countries accept the need for collective action on climate change. But national responses to it will need to vary according to each country's circumstances and potential. It is the job of governments to set laws and regulations to drive changes in business and public behaviour that mitigate greenhouse gas emissions and enhance our capacity to adapt to climate change.

For the developing countries, climate plans will need to be compatible with and supportive of their development goals. If developing countries are convinced that there are major development benefits to be drawn from climate action, such as faster long-term growth, better employment prospects and reduced poverty, they will be much more likely to embark on policies to put them on a low-carbon development path.

That is why UNEP's MCA4climate initiative, which provides valuable guidance to policy makers on drawing up and improving their climate plans taking account of the full range of socio-economic and environmental concerns, can prove highly effective in stimulating cost-effective national actions.

I wish this initiative every success.

Christiana Figueres,
Executive Secretary, United Nations Framework Convention on Climate Change (UNFCCC)

UNEP is the convenor of the MCA4climate initiative, which was launched at the end of 2009 with financial support from the Government of Spain. Our role is to bring together leading experts from around the world, to co-ordinate their analysis, to manage the consultation process and to ensure the legitimacy of their formal submissions. The UNEP team, part of the Division of Technology, Industry and Economics based in Paris and working on MCA4climate comprises:

- Şerban Scrieciu: project management, climate economics and policy evaluation framework.
- Sophy Bristow: multi-criteria decision support tool, case studies and outreach.
- Daniel Puig: programme management.

UNEP also acknowledges the assistance of Trevor Morgan in preparing this report.

Main partners

Several acclaimed international experts have contributed towards the development of the MCA4climate initiative and on different parts of the guidance package. Some have helped us define our approach and develop guidance documents, while others have applied the generic methodology to a specific mitigation or adaptation theme. Our main partners are listed below in alphabetical order:

- Frank Ackerman (Stockholm Environment Institute US): guidance on climate-change economics and critical issues for climate-policy analysis.
- Valerie Belton (University of Strathclyde): guidance on multi-criteria decision analysis and methodology development.
- Kornelis Blok (Ecofys): mitigation theme guidance on improving energy efficiency and saving energy.
- Ariane de Bremond (University of Maryland): adaptation theme guidance on increasing terrestrial ecosystems resilience.
- Zaid Chalabi (London School of Hygiene and Tropical Medicine): methodology development and adaptation theme guidance on reducing human health impacts and risks.
- William Cheung (University of East Anglia): adaptation theme guidance on increasing marine ecosystems resilience.
- Heleen de Coninck (Energy Research Centre of the Netherlands): mitigation theme guidance on capturing and storing emissions of CO_2.
- William Easterling (Penn State University): mitigation theme guidance on improving land use management.

- Paul Ekins (University College London): guidance on interactions between climate change and fiscal sustainability.
- Nathan Engle (Battelle — Pacific Northwest National Laboratory / Joint Global Change Research Institute): adaptation theme guidance on increasing terrestrial ecosystems resilience.
- Günther Fischer (International Institute for Applied Systems Analysis): adaptation theme guidance on reducing agricultural output losses.
- Stéphane Hallegatte (Centre International de Recherche sur l'Environnement et le Développement): adaptation theme guidance on increasing infrastructure resilience.
- Sari Kovats (London School of Hygiene and Tropical Medicine): adaptation theme guidance on reducing human health impacts and risks.
- Reinhard Mechler (International Institute for Applied Systems Analysis): adaptation theme guidance on reducing extreme weather event impacts.
- Kathleen Miller (National Center for Atmospheric Research, Colorado): adaptation theme guidance on improving water resources management.
- William Moomaw (Tufts University): mitigation theme guidance on increasing the share of low-carbon energy sources in the fuel mix.
- Trevor Morgan (Menecon Consulting): guidance on measurement, reporting and evaluation.
- Robert Nicholls (University of Southampton): adaptation theme guidance on improving coastal zone management.
- Stefan Speck (European Environment Agency): guidance on interactions between climate change and fiscal sustainability.
- Elizabeth A. Stanton (Stockholm Environment Institute US): guidance on developing baselines.
- Rashid Sumaila (University of British Columbia): adaptation theme guidance on increasing marine ecosystems resilience.
- Erika de Visser (Ecofys): mitigation theme guidance on improving energy efficiency and saving energy.

Other contributing experts

We would also like to acknowledge the contribution of other experts who have been involved in different stages of the MCA4climate initiative. These include: Robert Wilby (Loughborough University) and Bekele Debele Negewo (World Bank) on the Sana'a Basin, Yemen adaptation case study; Glynn Morris (AGAMA Energy) on the South African mitigation case study; Benjamin Jones (formerly with the IMF) on providing guidance on the linkages with fiscal policy; Jan Corfee-Morlot (Organisation for Economic Co-operation and Development) and K. Narayanan (Indian Institute of Technology Bombay) on the Mumbai, India adaptation case study; and Thanakvaro Thyl De Lopez and Anne Olhoff (UNEP Risø Centre on Energy, Climate and Sustainable Development) on helping define the themes and objectives of the project.

Steering committee

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External reviewers

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MCA4climate is a major new UNEP initiative providing practical assistance to governments in preparing their climate change mitigation and adaptation plans and strategies. It aims to help governments, particularly in developing countries, identify policies and measures that are low cost, environmentally effective and consistent with national development goals. It does this by providing a structured approach to assessing and prioritizing climate-policy options, while taking into consideration associated social, economic, environmental and institutional costs and benefits. In doing so, it seeks to counter the widely held perception that tackling climate change is costly, highlight the potential developmental benefits of addressing climate change and encourage action to that end.

1 Introduction

Background and rationale

At the climate talks in Cancún in December 2010, the long-term goal of limiting global warming to below 2 degrees Celsius in comparison with pre-industrial levels and Annex I and non-Annex I pledges of greenhouse gas emission reduction targets were formally incorporated into the UN Framework Convention on Climate Change. The Cancún Agreements further encourage non-Annex I parties — mainly developing countries — to develop low-carbon strategies and require them to take national appropriate mitigation actions (NAMAs) in the context of sustainable development aimed at achieving a deviation in emissions relative to business-as-usual emissions in 2020. They also take on board a commitment made by developed countries at the Copenhagen meeting a year earlier to provide $30 billion in fast-start finance in 2010-2012 for developing country NAMAs and national adaptation plans and actions (NAPAs), and to mobilize $100 billion a year of public and private finance by 2020.

In addition, the Agreements establish a Green Climate Fund to manage a portion of this funding. Many developing countries are still at an early stage of developing formal climate change policy plans, identifying specific mitigation and adaptation policy options, and deciding on which ones to adopt. There is widespread and increasing willingness to take this process forward and to take advantage of the funding that is on offer. But, in many cases, the planning process is complicated by the sheer complexity of the linkages and trade-offs between climate-related policy goals and broader developmental policy goals, as well as a lack of communication about the range of policy options available and how to go about evaluating their effects. Developing countries can often benefit from assistance in devising sound, low-cost and pro-development climate action plans.

Objectives and scope of the MCA4climate initiative

The MCA4climate initiative is intended to help meet this need, by providing practical help and guidance to governments, especially in developing countries, in formulating their climate-policy plans in the context of broader economic and social policymaking. It hopes to support current and future work on assessing how investment in low-carbon and climate resilient technologies could lead to job creation, growth, improved health prospects and other development benefits. Specifically, it enables governments to:

› Identify the developmental benefits of climate mitigation and adaptation in order to strengthen the case for such action and better integrate climate policy into national-level development-policy planning.

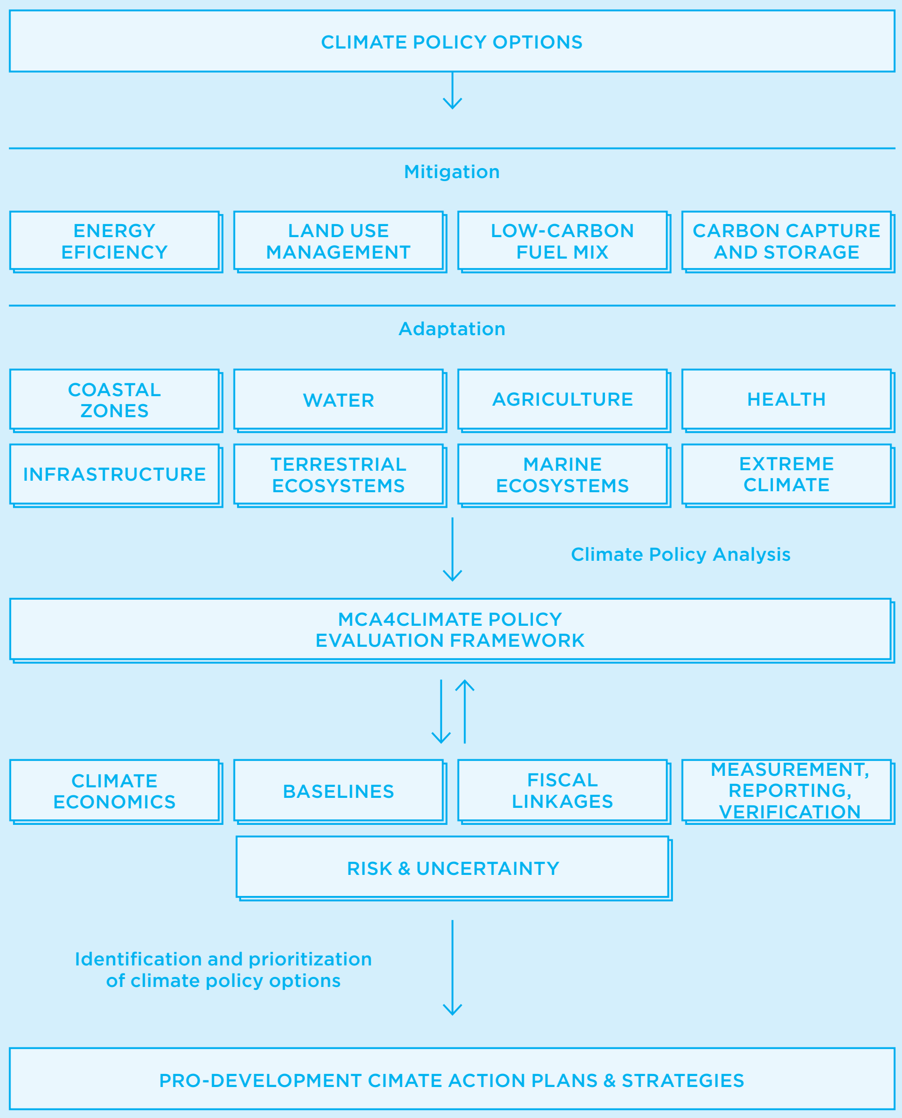
MCA4climate Introducing the MCA4climate initiative

› Assess systematically the complex linkages and trade-offs between the multi-faceted dimensions of climate change and its policy responses.
› Prioritize investments related to curbing greenhouse-gas emissions or adapting to climate change when deciding on the allocation of limited finance across a large array of possible climate actions.
› Deal with different or conflicting interests and objectives.

The principal way in which MCA4climate seeks to provide this assistance is through the application of the MCA4climate policy evaluation framework — a powerful analytical tool that has been developed specifically for the MCA4climate initiative by UNEP with assistance from a number of leading international experts. This framework, as the name indicates, is based on a multi-criteria analysis (MCA) approach — a well-established technique for aiding decision-making that has already been successfully deployed in non-climate areas of policymaking. The MCA4climate policy evaluation framework is intended to be used as a practical step-by-step tool for identifying and prioritizing mitigation and adaptation policies, consistent with developmental goals. It ensures that all the different dimensions of climate policies, including those that cannot be easily measured in monetary terms, are taken into consideration. It also facilitates the engagement of stakeholders in the policy-planning process.

At the heart of this framework is a hierarchical criteria tree containing a set of generic criteria, against which climate-policy planners can evaluate proposed policy actions and their potential contribution to a broad range of developmental objectives. Those policy actions have been categorized into 12 areas, or themes — four covering mitigation and eight covering adaptation — to provide a comprehensive guide to the various policy options available. For each theme, detailed criteria and indicators have been developed to enable the multi-dimensional effects of each policy to be evaluated. Recommendations have also been drawn up on appropriate forms of assessment and data sources. The potential interactions across the various themes have also been identified. In order to test the MCA4climate policy evaluation framework and demonstrate that it works, we applied the framework in three separate casestudies: two on adaptation (flood risks and infrastructure resilience in Mumbai, India and water management in the Sana'a Basin in Yemen) and one on mitigation (moving the electricity sector in South Africa towards low-carbon sources). Applying the MCA4climate policy evaluation framework — or, indeed, any approach to formulating climate policy — is confronted by a number of practical issues. We have analyzed in depth some of the most critical issues and prepared some guiding principles and practical recommendations on how to address them. These issues include assessing the economic implications of the

Figure 1: The structure of the MCA4climate initiative



various policy options, dealing with risk and uncertainty, developing and using baselines, understanding the fiscal implications of climate policies and undertaking the measurement, reporting and verification of policy actions and their effects. This guidance is intended to be of practical value to government officials directly involved in applying this framework or in analyzing climate policies more generally, as well as to other stakeholders involved in the climate policymaking process.

Purpose and structure of this report

This report is intended to provide a formal record of the results of the MCA4climate initiative to date. It contains four substantive sections, the findings of which can be used independently to address specific issues or as a whole to conduct a comprehensive evaluation of climate policy plans (Figure 1). The sections are as follows:

- Climate policy options: an overview of the nature of the policy challenge posed by climate change and of the policy-planning process, and a full description of the range of climate mitigation and adaptation policy options available categorized according to the 12 themes.
- The MCA4climate policy evaluation framework: a description of the climate policy evaluation framework, how it works and how it can be applied in practice across the themes. This includes the MCA4climate criteria tree which is a practical tool for evaluating the multiple dimensions of climate policies.
- Case studies: an exploration of the practicalities of applying the MCA4climate framework to real policy problems in three different locations. Each case study was designed to test different elements of the framework, and the lessons learnt contributed to the development of the overall MCA4climate initiative.
- Guiding principles for climate-policy planning: a summary on cross-cutting aspects of climate-policy planning and analysis, including practical recommendations.

Further information on the MCA4climate policy evaluation framework and approach, all of the detailed reports on each of the themes (theme reports), the guidance on critical aspects of climate-policy planning (also labelled as guiding principles) and the case studies, together with more information about the background to the MCA4climate initiative, can be downloaded from the MCA4climate website: www.mca4climate.info.

Next steps

It is hoped that this report will encourage policymakers in developing countries and other stakeholders to consult and make use of the theme reports and guidance documents and to consider the possibility of applying the MCA4climate policy evaluation framework at the national level. It is envisaged that applying the framework fully will require the direct involvement of external experts who have been engaged in the initiative or are familiar with using this framework. The next steps that UNEP envisages in taking the MCA4climate initiative forward are:

› Building partnerships: UNEP is currently working with the French development agency (AFD) and other bilateral agencies to promote the goals of the MCA4climate initiative at the national level.
› Piloting in countries: work is underway in Mexico and preparations are well advanced in other emerging economies.

Government officials and other stakeholders looking to learn more about the MCA4climate initiative and how it could help climate-policy planning in your country should contact Mark Radka at unep.tie@unep.fr.

All Parties to the Conference are required to develop climate policies in order to contribute to the overall objective of the United Nations Framework Convention on Climate Change to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system. The Convention recognizes the importance of scientifically sound, long-term national plans and strategies to mitigate climate change by reducing the sources or enhancing the sinks of greenhouse gases or to adapt to it, though there is no legal requirement on Parties to prepare a plan as such. There is also a growing recognition of the need to prepare for and adapt to climate change as a certain degree of change appears to be inevitable.

A climate plan sets out how a package of policy instruments and specific measures are to be implemented and how they are expected to contribute to meeting stated policy goals. In formulating that plan, policymakers must identify and evaluate mitigation and adaptation policies drawn from the full range of options available, taking account of national circumstances.

2 Policy options for mitigation and adaptation

Developing a climate-change policy plan

A national climate policy comprises four elements:

- A statement of objectives, or policy goals.
- A strategy, or a plan, for achieving them.
- A set of policy instruments and specific measures.
- An institutional framework, for both formulating and implementing the policy.

A climate-policy plan, therefore, is the means by which a government goes about trying to achieve its overall policy goal. That goal is usually focused on contributing to international efforts to mitigate the impact of climate change, by reducing anthropogenic emissions of greenhouse gases. Increasingly, the goal involves adapting to climate change that will result from past and future emissions.

The plan may involve quantitative targets for emissions, or reductions relative to a baseline: all Annex I and some non-Annex I countries have adopted such targets. Those non-Annex I countries that have not committed themselves to quantitative emissions reductions are required under the Framework Convention to take NAMAs. Although there is no strict definition of what a NAMA is, it is typically taken to refer to the implementation of a set of policy instruments or specific projects that result in a reduction in emissions below a baseline or business-as-usual. Although there is no requirement on any country under the Convention to adopt NAPAs, the Cancún Agreements do include measures, notably the Cancún Adaptation Framework, to enhance adaptation efforts by all countries and help the least developed and most vulnerable countries develop and implement NAPAs.

The climate-policy plan comprises a specific set of instruments or measures (often called simply policies) that are to be implemented over a given timeframe. The policies that actually make up the plan are drawn from a range of options for mitigating the impact of climate change or adapting to it. The MCA4climate initiative categorizes these options into 12 areas, or themes — four of which concern mitigation and eight adaptation (Table 1). The themes chosen for the mitigation actions correspond to the main ways in which greenhouse-gas emissions can be abated, while the adaptation themes mirror the issues covered by the Intergovernmental Panel on Climate Change in its most recent assessment report (IPCC, 2007), with the addition of the theme on extreme-weather events. The mitigation themes were not based on those of the IPCC, which is made up of sectors such as industry or transport, as it was felt that this would result in excessive overlap in view of the type of analysis being undertaken for the MCA4climate initiative.

In practice, governments need to balance action to mitigate greenhouse-gas emissions and action to adapt to actual and imminent

MCA4climate Policy options for mitigation and adaptation

Table 1: Mitigation and adaptation themes

THEME	NOTES
MITIGATION	
Improving energy efficiency and conserving energy	Adopting technologies or practices to provide the same energy service with fewer energy inputs (increased energy efficiency) and/or changes in behaviour that result in reduced demand for energy services (energy conservation).
Improving land-use management practices	Increasing carbon absorption or reducing carbon-dioxide emissions via changes in forestry or agricultural practices (mainly through livestock and fertilizer input management), by reducing and avoiding deforestation, forest management, forest restoration, afforestation and reforestation.
Increasing the share of low-carbon energy sources in the fuel mix	Reducing the carbon content of the fuel mix, including switching between fossil fuels (for example, from coal to gas) and from fossil fuels to nuclear energy or renewable sources of energy (solar energy, wind energy, geothermal energy, biomass energy, hydropower, tidal and marine energy).
Encouraging carbon-dioxide capture and storage	A process involving the separation and capture of carbon dioxide from industrial and energy-related sources, and its transportation and long-term storage underground.
ADAPTATION	
Improving coastal zone management	Integrating likely ecological and human impacts of climate change into management plans and practices for low-lying areas and shallow coastal waters.
Reducing human health impacts and risks	Adopting emergency preparedness and response mechanisms to respond to climate-related causes of ill-health, notably under-nutrition, diarrhoeal diseases and malaria.
Reducing agricultural output losses	Maintaining or enhancing agricultural productivity (notably, by improving water use, agricultural input, soil management, land-use management, and crop-diversification practices), and increasing the resilience of crops and livestock to adverse climatic conditions.
Increasing infrastructure resilience	Adopting emergency preparedness and response mechanisms to respond to climate-related impacts on equipment, utilities, enterprises, installations and services.
Improving water resource management	Integrating possible impacts of climate change on freshwater systems and their management, including seasonal shifts in streams flow, salinization, and flooding and drought risks.
Increasing terrestrial ecosystems resilience	Adopting natural resource management techniques such as expansion of reserve systems and actions to reduce climate change-induced stresses on terrestrial ecosystems.
Increasing marine ecosystems resilience	Adopting natural resource management techniques to reduce climate change-induced stresses on marine ecosystems and their resilience.
Reducing extreme weather event impacts	Adopting emergency preparedness and response mechanisms to respond to severe but infrequent climate-related events.

Table 2: Policy options to improve energy efficiency and conservation

INSTRUMENT	POLICY OPTIONS
Market-based	Energy/carbon pricing. Tradable certificates. Subsidies and tax breaks (exemptions, credits and rebates). Loan facilities.
Regulatory	Energy efficiency performance standards for equipment and appliances. Mandatory improvements in efficiency or intensity (such as for fleet vehicle purchases).
Public investment	Research and development. Infrastructure provision.
Information-based	Labelling. Energy-performance certificates. Training and capacity-building.
Voluntary agreements	Agreements on energy efficiency and/or intensity improvements with industry.

climate change. This balance needs to take account of the type of commitment made to reduce greenhouse-gas emissions, the scale and nature of the risks from climate change, and the cost of adaptation. All these factors depend on national circumstances.

Each of the themes is described below, including the principal policy options, which are generally categorized according to the type of instrument: market-based, regulatory, public investment, information-based, and voluntary agreements or international co-operation. The classification is only indicative and provides a consistent taxonomy across all themes. The analysis developed by the theme experts is intended to provide an in-depth reference resource to inform the development of potential policy and action plans for evaluation.

Mitigation policy options

Improving energy efficiency and conserving energy

Improving energy efficiency refers to a reduction in the amount of energy consumed in providing an energy service, such as heating, cooling or mobility. Energy conservation is the savings in energy use from forgoing an energy service, such as walking instead of using a car. Energy intensity measures the amount of energy used in aggregate for economic activity; at the highest level, energy intensity is measured as the total primary energy consumption [1] per unit of economic output or gross domestic product (GDP), while at the lowest level, it can be measured for individual processes or individual appliances. Energy intensity is affected by energy efficiency, but also by economic structure. A country with a large industrial sector may use energy relatively efficiently but have a high intensity.

In many countries, energy is used inefficiently or wastefully in a wide range of applications. Often, this is because the capital stock is obsolete and could be replaced by modern equipment and appliances which use energy much more efficiently. In some cases, prices are held below market levels, often for social reasons, reducing the incentive for energy users to conserve energy or use it more efficiently. Government policies can drive more efficient energy use by persuading, encouraging or obliging households, motorists, businesses and public bodies to change their energy-consumption behaviour and their purchases of energy-using equipment, appliances and vehicles, through a variety of market-based, regulatory and information-based instruments. Governments can also directly affect energy use by investing directly in infrastructure or by negotiating voluntary agreements with businesses to reduce energy use (Table 2). Major barriers against energy-efficiency improvements in developing countries include lack of awareness on the importance and the potential of energy-efficiency improvements, lack of financing, lack of qualified personnel and insufficient energy service levels. Information programmes are especially important in developing countries, where lack of information has been identified as a major barrier for energy efficiency and renewable-energy investments. Subsidy reform, involving raising energy prices to full market levels, is generally among the least-cost policy options and may be 'no-regrets', i.e. the net cost to the economy is at or below zero, not even allowing for the environmental benefits from lower emissions of greenhouse gas and pollutants. This is because reducing energy use may bring about important economic benefits, including cost savings, lower imports or increased availability of energy for export and a reduced burden on the central government budget or state-owned enterprises.

Improving land-use management practices

Climate change can be mitigated through improving land-use management practices that increase carbon absorption or reduce emissions of carbon dioxide (CO_2). This can be achieved through changes in forestry — by reducing or avoiding deforestation, better forest management, forest restoration, afforestation or reforestation — or in agriculture — by better soil carbon management and the use of bio-char to sequester carbon and by reducing emissions with better livestock and fertilizer management. These activities are collectively known as Land Use, Land-Use Change, and Forestry (LULUCF). Increasing carbon in the terrestrial biosphere is a relatively low-cost way to help mitigate the increasing concentration of CO_2 in the atmosphere, while providing co-benefits, such as

1 Energy extracted or captured directly from natural resources such as crude oil, hard coal, natural gas, or produced from primary commodities or sources, such as uranium, hydropower or solar energy.

MCA4climate Policy options for mitigation and adaptation

protecting forests, biodiversity, water quality and soil fertility. Land-use management practices in agriculture can mitigate climate change through carbon sequestration and emissions reduction. Carbon sequestration can be boosted mainly through agronomy (on-farm practices that increase crop and pasture productivity, thereby generating more biomass and increasing carbon uptake); management of residues and water to reduce methane emission and increase soil carbon, notably in rice growing; optimized grazing practices; and restoration of degraded land. Several agricultural practices have shown promise for reducing agricultural carbon emissions, including nutrient management; conversion to cover crops; fire management; and management of organic soils and manure. In forestry, the principal climate change mitigation practices include reducing or avoiding deforestation, forest management and restoration; and afforestation and reforestation. The most effective short-term strategy for mitigating climate change through forestry is undoubtedly to reduce rates of deforestation. There is a rich portfolio of policy instruments available to governments to promote climate change mitigation through improved land-use management (Table 3). In practice, LULUCF mitigation policies will need to be formulated and implemented within the context of broader agricultural and forestry policies. In many cases, the objectives of the latter policies

Table 3: Policy options to improve land-use management practices

INSTRUMENT	POLICY OPTIONS
Market-based	Tradable permits for allocating emissions/carbon absorptions. Taxes and charges, e.g. to discourage forest clearing.
Regulatory	Mandatory actions concerning on-farm practices and technologies, such as GPS-assisted precision fossil fuel-based fertilizer applications (in agriculture) or a performance standard for lowering the rate of forest-to-agricultural land conversion (in forestry).
Public investment	Research and the development of new knowledge and innovative land-use practices and technologies, e.g. to improve crop productivity.
Information-based	Public relations and education campaigns and mandatory emissions disclosures to encourage climate change mitigation behaviour (e.g. to educate farmers that conservation tillage not only increases carbon absorption in the soil, but also improves soil water-holding characteristics).
International co-operation	Multi-lateral treaties to voluntarily reduce emissions or sequester carbon.

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may conflict with the goal of mitigating climate change, especially where they are aimed at maintaining farmer livelihoods through rural development and underpinning food security.

Increasing the share of low-carbon energy sources in the fuel mix

Globally, nearly 60% of heat of global warming is caused by the CO_2 that is emitted from the combustion of fossil fuels (IPCC, 2011). Methane leaks from natural gas and oil production and use and other greenhouse gases emitted from burning fossil fuels, as well as black carbon from burning biomass, are additional sources. Fossil fuels currently account for over 80% of primary energy use worldwide (IEA, 2010a). And fossil-fuel consumption is set to continue to grow: without a change in government police, global fossil energy use would expand by 44% between 2008 and 2035 — a development that would be compatible with an increase in global temperature of more than 6° Celsius (IEA, 2010b).

Individuals and businesses consume energy for the services they provide, including cooking, lighting, refrigeration, communications and entertainment, mechanical work, mobility, heating for comfort and hot water. End-use energy to supply these services is provided by different energy carriers such as the heat generated by burning fuels or electricity. The end-use carriers of energy come through a technological conversion process that utilizes a source of primary energy such as biomass or fossil fuels, nuclear energy, solar, wind, hydro, geothermal or ocean energy. With economic development and population growth, the world's demand for end-use energy will certainly grow. Consequently, to mitigate climate change, it will be necessary to set in motion a rapid transformation of the world's energy system away from fossil fuels as primary energy sources and towards low-carbon alternatives — essentially nuclear power and renewable energy sources.

There are number of policy instruments that governments can use to encourage or force such a transformation (Table 4: See next page). In principle, market-based instruments are the most economically efficient approach, but other instruments may prove more effective as a result of market barriers.

Because needs for energy services are so different for societies at different stages of development, the appropriate policies needed to boost the role of low-carbon fuels to supply those services also differ:

› Least developed countries are in need of the most basic energy services. Consequently, the main policy objectives are likely to include improving cooking services through the introduction of improved stoves; the deployment of distributed renewables-based technologies such as solar-powered lanterns, radios and mobile phone chargers; and creating electricity services for

Table 4: Policy options to increase the share of low-carbon energy sources

INSTRUMENT	POLICY OPTIONS
Market-based	Carbon cap and trading schemes. Carbon and energy taxes (that penalize fossil fuels). Subsidies to renewables and nuclear energy, e.g. feed-in tariffs and low interest rates. Remove subsidies to fossil fuels.
Regulatory	Mandates on the share of low-carbon fuels/technologies. Remove barriers to innovation, such as restrictions on distributed generation or maximum amounts of renewable energy on the grid. Establish clear interconnection rules for power grids and ensure that they encourage the use of efficient low-carbon technologies.
Public investment	Direct investment in low-carbon energy infrastructure or technologies. Spending on research and development of low-carbon sources.
Information-based	Awareness-raising and educational programmes. Education and training in engineering and policy. Provide assessments of low-carbon resources.
International co-operation	Co-operative programmes on technology research and development, e.g. through partnerships and IEA implementing agreements.

urban areas such as distributed generation. The most important policy actions that governments of these countries can establish are those that build capacity.

› Developing country policies concern primarily more extensive low-carbon electrification of services in rapidly growing urban regions while still meeting the needs of rural users. Economy-wide policy instruments need to be implemented alongside the development of specific large-scale low-carbon projects. Removing subsidies for fossil fuels is an important policy action needed in many developing countries.

› Emerging economies policy needs are similar to those for developed countries. Financial as well as regulatory policies have proven effective in moving to low-carbon technologies for delivering energy services. These countries often have the capacity to manufacture and install major low-carbon technologies, and have policies in place to encourage those industries. For example, China and India have become major producers of wind turbines and solar PV panels.

› Developed countries have well-developed energy systems that vary enormously in terms of carbon intensity. This presents a challenge since there is so much of the energy system that is 'locked-in' to existing high-carbon infrastructure. These countries need to use a combination of policy instruments to shift investment towards low-carbon technologies and accelerate the retirement of existing fossil-energy-based capital stock.

Encouraging carbon-dioxide capture and storage

Carbon-dioxide capture and storage (CCS) is a technology that reduces greenhouse-gas emissions by separating CO_2 from the flue gases of a large, stationary point source, transporting it, and isolating it from the atmosphere by injecting it into a geological reservoir that is suitable for permanent storage, such as a depleted oil or gas field (IPCC, 2005). In principle, CCS can reduce CO_2 emissions from power plants or large industrial facilities that burn fossil fuels by up to 85% compared with conventional technology.

However, CCS has yet to be deployed commercially in the power and industrial sectors, and the effectiveness of the technology and its cost remain uncertain. There are also uncertainties about the safety and integrity of long-term geological storage of CO_2 and whether sufficient suitable storage capacity exists to make this a widespread option. CCS has so far been used solely in the oil and gas industry, in instances where there is a need to separate out CO_2 from natural gas; the CO_2 is then used either for enhanced oil recovery, or is stored permanently underground. A number of demonstration plants involving the use of the technology in power generation are under development or planned in several countries, the biggest being the 1GW FutureGen project in the United States. The demonstration

Table 5: Policy options to promote CCS

INSTRUMENT	POLICY OPTIONS
Market-based	Carbon price or tax. Tax credits. Carbon emission standard.
Regulatory	Mandatory deployment of CCS for coal- or fossil-fuelled installations.
Public investment	R&D support. Demonstration subsidy. Funding pipeline network. Funding of storage assessments.
Information-based	Academic education programmes. Regulatory capacity building. Public engagement programmes around projects. Information portal and documentation.
International co-operation	Regional technology knowledge networks.International demonstration fund for CCS.

phase is likely to last for over a decade. In the longer term, CCS could emerge as a potential mitigation option in certain locations. There are a number of ways in which a government can seek to encourage the development, demonstration and deployment of CCS technology if it decides that CCS should from part of its portfolio of mitigation actions (Table 5: See previous page). Most of these policy options, especially related to awareness-raising and public investment, would probably be a pre-requisite for CCS to take off. Some economic instruments are complementary, especially those addressing different technological maturity phases, even to the extent that the one is not effective without the other; other instruments would address the same problem.

Adaptation policy options

Prioritizing adaptation actions at the global level is hard because of the huge array of potential climate impacts, the different types of societies they will hit and the wide range of potential adaptation strategies and measures. For any given country, the choice of appropriate policy options, as well as decisions on timing, sequencing and levels of investment, depend very much on the specific national context and the range of projected climate changes and their consequences.

Improving coastal zone management

Climate change and its causes are expected to lead to major changes in coastal areas including decreasing seawater pH, rising sea levels and sea surface temperatures, and changing storm, wave and run-off characteristics. Rising global-mean sea levels due to thermal expansion and the melting of land-based ice are already being observed, and this rise is likely to accelerate through the 21st century: the IPCC's Fourth Assessment Report projects a rise of 20 to 60 centimetres by the 2090s (IPCC, 2007). Some recent analyses have suggested that, while highly unlikely, a rise of 2 metres by 2100 cannot be discounted. There is also increasing concern about higher extreme sea levels due to more intense storms superimposed on these mean rises, especially for areas affected by tropical storms. While higher sea levels only impact coastal areas, these are the most densely populated and economically active land areas on Earth and they also support important and productive ecosystems that are sensitive to sea-level change. It is fairly certain that sea level will continue to rise due to human-induced global warming far beyond the 21st century due to the large thermal inertia of the oceans.

Three distinct generic types of adaptation actions to rising sea levels can be identified:

› Protect, i.e. reduce the probability of rising sea levels occurring.
› Accommodate, i.e. reduce its impacts.
› Retreat, i.e. reduce exposure to it.

Some interacting factors, such as sediment supply, appear twice as they can be influenced by both climate and non-climate factors. [P] Protection, [A] Accommodation, [R] Retreat. Sources: Nicholls and Tol (2006).

Table 6: Natural system effects of sea-level rise

NATURAL SYSTEM EFFECT		INTERACTING FACTORS: CLIMATE	INTERACTING FACTORS: NON-CLIMATE	SOCIO-ECONOMIC SYSTEM ADAPTATION
Inundation, flood and storm damage	Surge (sea)	Wave/storm climate; erosion; sediment supply	Sediment supply; flood management; erosion; land claim	Dykes/surge barriers [P]. Building codes/ flood-wise buildings [A] Land-use planning/haz-ard delineation [A/R]
	Backwater effect (river)	Run-off	Surge (sea)	
Wetland loss/ change		CO_2 fertilization; sediment supply	Sediment supply; migration space; direct destruction	Land-use planning [A/R] Managed realignment/ forbid hard defences [R] Nourishment/ sediment management [P]
Erosion		Sediment sup-ply; wave/storm climate	Sediment supply	Coastal defences [P] Nourishment [P]Building setbacks [R].
Saltwater intru-sion	Surface waters	Run-off	Catchment man-agement and land use	Saltwater intrusion barriers [P]. Change water abstraction [A/R]
	Groundwater	Rainfall		
Rising water tables/impeded drainage		Rainfall Run-off	Land and aquifer use; catchment management	Upgrade drainage systems [P] Polders [P] Change land use [A] Land-use planning/hazard delineation [A/R]

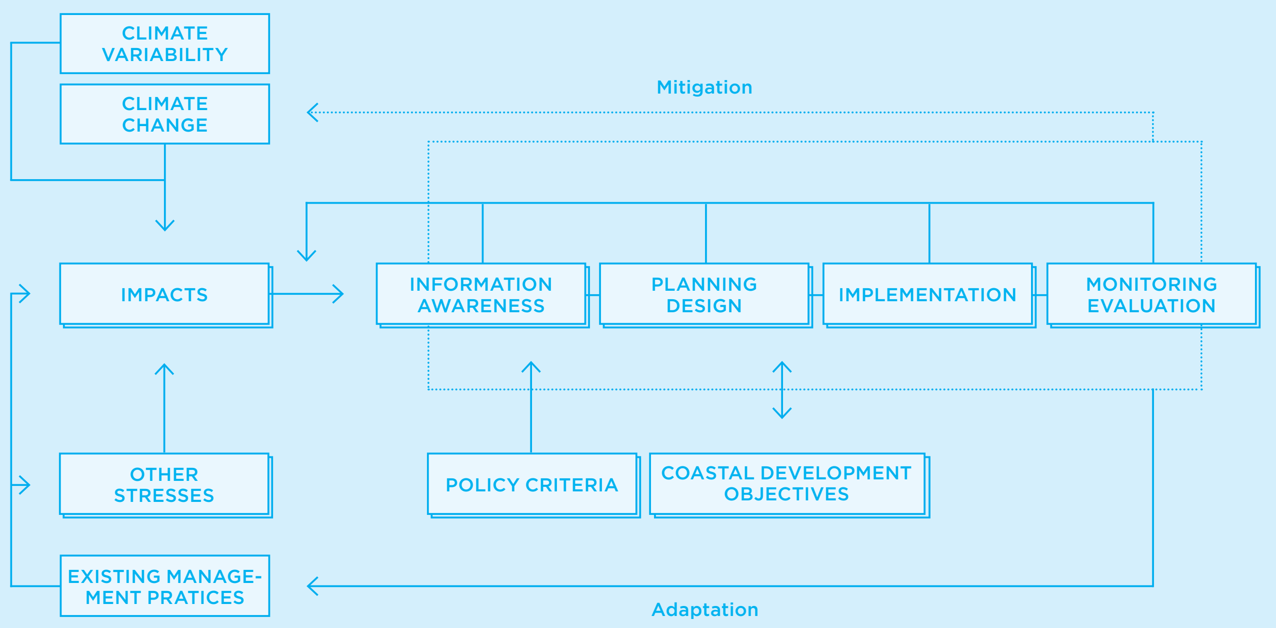
The application of these measures needs to take place within the context of coastal management, which is concerned with managing all the drivers threatening the coastal zone, not just climate change. Given that our scientific understanding is far from complete in coastal areas, there is much to be learnt from monitoring our interventions. This is consistent with adaptive management approaches (Figure 2).

There is a very large number of individual measures available to implement these actions. The main measures concern the construction of physical barriers and changes to land use and are presented in Table 6 (See previous page). In addition, enhancing the capacity for coastal management is also an important step in enhancing the capacity to adapt to climate change in coastal areas.

Reducing human health impacts and risks

The potential impacts of climate change on population health include a wide range of diseases and health outcomes, from infectious diseases and chronic diseases to malnutrition and injuries. Adaptation, broadly defined, would include all activities or interventions that reduce or prevent these additional cases of disease or deaths. An obvious example is the health impacts of extreme weather events, such as heat waves, floods and droughts. There is a wide range of policy options in the area of traditional public health activities that focus on disease prevention and control policies in low and middle income countries (Table 7). Some of these options can be applied equally to developed countries. There are many other actions outside the health sector that are also needed to improve health, which

Figure 2: Conceptual framework for coastal adaptation



Policy options for mitigation and adaptation
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Table 7: Policy options to reduce human health impacts and risks

INSTRUMENT	POLICY OPTIONS
Market-based	Subsidize or offer tax exemptions to pharmaceutical companies to provide medications (e.g. cholera immunization).
Regulatory	Introduce regulations (e.g. water and air quality standards).
Public investment	Improve infrastructure, capacity and access to primary and secondary healthcare services. Carry out research to evaluate ex ante the effectiveness and cost-effectiveness of policies to reduce attributable health impacts. Increase healthcare work-force and invest in their training. Provide up-front public invest-ment to purchase drugs (e.g. insecticide-treated bed nets for malaria) or develop new drugs (e.g. anti-malarials).
Information-based	Develop and implement health forecasting and early warning system. Increase investment in health-promotion programmes.
International co-operation	Provide global health forecasting systems

are addressed by the other climate-policy themes. These actions include, for example, the strengthening of coastal and river defences against floods and improving water supply and sanitation. Health effects should always be considered in decision-making concerning environmental policies, particularly those policies that may cause harm. Climate-change impacts and health priorities will vary greatly both between and within countries.

Reducing agricultural output losses

Widespread hunger and rising global food demands necessitate better use of the world's water, land and ecosystems. With world population expected to grow to about 9 billion by 2050, agricultural production will need to increase by about 70% globally and by 100% in developing countries. An enormous effort is required to achieve such growth. Some 1.6 billion hectares of land are currently used for crop production, with about 1 billion under cultivation in developing countries. As people strive to get the most out of land already in production or exploit virgin territory to develop more agricultural land to grow food, the damage inflicted on the environment will grow. About 40% of the world's arable land is already degraded to some degree and will be further impacted by climate change, including by expected extreme weather events and climate variability.

Table 8: Policy options to reduce agricultural output losses

INSTRUMENT	POLICY OPTIONS
Market-based	Review and adjust agricultural subsidies and taxes, e.g. to support new technology, crop varieties/seed material, the introduction of improved climate-change resistant livestock breeds and improved and efficient irrigation technologies. Water pricing. Payment for ecosystem services, such as watershed protection, carbon sequestration and biodiversity protection. Create local food and feed banks for people and livestock. Risk bearing and sharing schemes, national disaster funds and crop insurance.
Regulatory	Review agricultural policies for consistency with climate change adaptation and mitigation policies. Impose caps on irrigation water use; regulate irrigation water distribution. Establish integrated land use planning and zoning. Promote stakeholder-led development planning and adaptation strategies.
Public investment	Develop new crop varieties for improved resistance to drought, heat and salt tolerance and climate-change resistant livestock breeds. Establish programmes for soil-fertility maintenance. Improve management and maintenance of existing water supply. Dam construction for irrigation. Build desalination plants. Maintain emergency food stocks.
Information-based	Raise public awareness on climate change and adaptation. Improve forecasting for farming, extreme events and disaster management and develop monitoring and early warning systems (weather, crop yield; pest & disease). Establish/enhance education and outreach programmes on conservation and management of soil and water. Provide education and capacity building for improving farm level production decisions and for local communities to assist in disaster relief actions.
International co-operation	Negotiate agreements on sharing transboundary water resources, technology transfer, gene banks/germplasm, pest and disease monitoring and warning, agricultural knowledge sharing. Support international data collection and analytical capacity building, relief and reconstruction programmes and new risk hedging instruments and international insurance pools.

Food insecurity is compounded by water scarcity. Some 30 countries already face water shortages, and by 2050 this number could increase to over 50 countries, most of them in the developing world. About one-quarter of the world's population live in areas categorized as physically water scarce and one-sixth in areas of economic water scarcity (UNESCO [United Nations Educational, Scientific and Cultural Organization] [2006], Water — A Shared Responsibility: The United Nations Water Development Report 2, UNESCO/Berghahn Books, Paris/New York). While current research confirms that crops would respond positively to elevated CO_2 in the absence of climate change, human activities — primarily fossil fuel burning and deforestation — are causing massive atmospheric

concentrations of greenhouse-gas emissions, leading to higher temperatures, altered precipitation patterns, and increased frequency of extreme events, such as drought and floods. This combination of factors will likely depress agricultural yields and increase food production risks in many world regions in the future, particularly in many of the current food-insecure countries.

As noted in IPCC (2007), the array of potential adaptive responses available to human societies is very large, ranging from purely technological (e.g. sea defences), through behavioural (for example, altered food choices) to managerial (e.g. altered farm practices) and to policy (such as planning and regulations). There are also many barriers, limits and costs for adaptation, ranging from environmental, economic and informational to socio-cultural and behavioural. There are similarly a range of policy options available to governments to drive these responses (Table 8).

Increasing infrastructure resilience

Physical infrastructure, such as water supply, sanitation, energy, transportation and communication services, and institutional systems like delivering healthcare, security, and fire control and other services, are vulnerable to long-term climate change in two ways: it influences average weather conditions and can, thereby, reduce infrastructure service quality, quantity or reliance; and it can give rise to more frequent extreme weather events. Changes in infrastructure design, operation or management, including response mechanisms, are required to increase the resilience of infrastructure so as to minimize the negative impacts of these threats when they materialize.

Formulating policies to achieve this is complicated by the fact that future climate change is still extremely uncertain. Nonetheless, the resilience of infrastructure and risk-management systems in most countries is already sub-optimal regardless of any potential change in climate, so polices to increase resilience are often 'no-regrets'. This would be the case in many developing countries for electricity networks or drinking water networks. Such policies cannot, therefore, be assessed purely from a climate-change perspective.

There is a broad range of options, categorized by type of instrument, that can be implemented to increase short-term resilience (the ability to cope with extreme weather events) or long-term resilience (the ability to cope with longer-term changes in environmental conditions, like gradual soil deterioration) or both (Table 9). These options are sometimes synergetic, i.e. they increase both short-term and long-term resilience, but they sometimes conflict, i.e. there is a trade-off between the two. In practice, there can be trade-offs between infrastructure resilience and efficiency in normal times; for instance, redundancy of assets may increase resilience (for example, an ensemble of two bridges is more resilient than a single bridge), but also increases costs. So there may be little incentive for infrastructure investors and managers to increase resilience without government policies to either oblige or encourage them to do so.

Improving water resource management

Climate change could have substantial impacts on water availability, water quality, the frequency and magnitude of flood and drought events, and on aquatic ecology. There is considerable evidence that global warming will result in a general acceleration of the global hydrologic cycle — the continuous movement of water on, above and below the surface of the Earth. Surface water will evaporate more readily and the moisture-holding capacity of the atmosphere will increase, leading to an overall increase in atmospheric water vapour and a greater likelihood of both extremely heavy precipitation events and longer, hotter dry spells. Evidence from climate models points to increased precipitation in far northern and southern latitudes, drier conditions in many subtropical locations and wetter again in some areas along the equator, though the extent of these changes is highly

Table 9: Policy options to increase infrastructure resilience

INSTRUMENT	POLICY OPTIONS
Market-based	Policies to create incentives to promote resilience, such as penalties for unreliable infrastructure performance or subsidizing enhanced reliability.
Regulatory	Technical building codes and construction standards and regulations, and procedural standards (such as requirements to carry out vulnerability studies, adapted to take into account climate change and the resulting change in natural risks).
Public investment	Additional investments by government and/or local authorities (including through public-private partnerships) to increase infrastructure reliance and resilience, either through retrofitting existing infrastructure, building new infrastructure or duplicating existing infrastructure to augment redundancy and resilience.
Information-based	Gathering and dissemination of information by public bodies, for example, through the funding of research and development. For example, in the United Kingdom, the UKCIP programme handles both research and accessibility of information to businesses, regional government agencies and households.
Institution-based	Pooling of emergency response capability. Adapting crisis-management systems can be a 'no regret' measure as it can often be justified by existing natural risks.

uncertain. In addition, warmer air temperatures will have significant impacts on the timing of snow-melt run-off, evaporative losses from soil and surface water, and plant-water use. Rising sea levels will cause saline intrusion into coastal aquifers as well as flooding of some coastal areas.

Many countries are already struggling to manage water effectively and climate change will complicate that challenge. Water and infrastructure management will need to adapt to deal with the threats to humans, aquatic environments and to ecosystems generally posed by the changes in hydrologic systems that are expected to be caused by climate change. The threats to humans include increased vulnerability to floods and droughts, and longer-term changes in water availability and quality, as well as greater health risks caused by contaminated drinking water, insufficient water for drinking and sanitation and exposure to diseases spread by mosquitoes and other water-dependent vectors. Ensuring sufficient water supply for irrigation, which now accounts for approximately 70% of all water withdrawn from streams, lakes and aquifers for human use, will be a major focus of attention. Sound water-policy planning has to strike a balance between protecting human uses of water as a resource and protecting water's role in maintaining healthy ecological systems. So, policymakers need to explicitly consider how any specific policy or measure could affect the many inter-linked facets of water use and its ecosystem services. In doing so, they need to take account of the unpredictability of hydrologic systems and the uncertainty about how climate change will affect them. This requires developing a strategy that is robust to the plausible range of future hydrologic change, while preserving both resilience to surprises and options to modify plans as the need arises. There are many policy options to improve water resource management in ways that would help to maintain water quality and the reliable provision of water for human and ecological uses despite the impacts of climate change (Table 10: See next page). In many cases, appropriate policy design will require basic information on the state of the water resource system, existing water-use practices, hydrologic variability over time, and the status and sensitivity of water-dependent ecological resources. Policies focused on building that information base are often good candidates for early investment and continued support.

Increasing terrestrial ecosystems resilience

Terrestrial ecosystems are vital to the maintenance of human well-being and play a vital role in the global carbon cycle, removing three gigatonnes of carbon from the atmosphere every year. Accelerating changes in the global climate are expected to have widespread negative effects on terrestrial ecosystems, through

Table 10: Policy options to improve water resource management

INSTRUMENT	POLICY OPTIONS
Market-based	Introduce metering and volumetric pricing of water use, including irrigation. Remove subsidies on electric power and diesel fuel for irrigation pumping. Allow water-right owners to sell or lease water to other users.
Regulatory	Improve documentation of water entitlements, clarify quantitative and temporal limits, and define how entitlements will change with changes in water availability. Create a formal legal role for community organizations in defining, documenting and enforcing water entitlements, and forums for watershed to basin-scale water policy-planning.
Public investment	Build reservoirs, flood by-pass infrastructure with active groundwater recharge projects (where feasible) and flood-control projects as an alternative to traditional dams and levees. Encourage investment in small-scale rain-water capture systems and urban storm drainage systems. Relocate or redesign sewerage-treatment infrastructure to avoid damage/malfunction due to flooding.
Information-based	Establish network of weather stations, stream gauges and monitoring wells, and publish real-time information on watershed/aquifer conditions. Establish a phone network to convey flash-flood warnings. Set up educational programmes on efficient irrigation practices.
International co-operation	Establish joint scientific programmes among nations sharing trans-boundary water resources. Identify rigidities in existing treaties and environmental agreements relating to these water resources and evaluate their potential consequences. Negotiate contingency plans and joint investment projects with neighbouring countries.

altered patterns of temperature and precipitation, which govern the rates of many biological and chemical reactions and control critical ecosystem processes. Global distribution of vegetation is expected to shift pole-ward and altitudinally, prompting shifts in species' climatic zones, patterns of migration and abundance, while warmer (equatorial) ecosystems are expected to experience increased vulnerability to pests, fire and competition. Such shifts in terrestrial ecosystem processes will affect humans everywhere; communities and regions where livelihoods are closely tied to natural resources are especially vulnerable. Profound changes in resource-management systems are, thus, required to respond to and limit biodiversity loss, reduced access to clean water, and altered forest and crop productivity and yields. Improving terrestrial ecosystems' resilience — defined as the capacity to maintain similar structure, functioning and feedbacks despite shocks and perturbations — must form a central part of climate adaptation actions.

There are a host of adaptation options for increasing the resilience of terrestrial ecosystems, many of which are based on

well-established, classical natural resource management approaches (some of the main types of policies are summarised in Table 11). In general, simply implementing what is already known to protect terrestrial ecosystems will likely be beneficial for adapting to climate change. However, policymakers need to consider a number of factors that make some adaptation policies unique, including the need to take both fast-moving variables such as extreme-weather events and slow-moving variables such as changes in hydrology and sediment concentration into account. And the impact on humans of changes that have already occurred need to be considered: an adaptation policy that restores an ecosystem to its 'natural' state,

Table 11: Policy options to increase terrestrial ecosystem resilience

INSTRUMENT	POLICY OPTIONS
Market-based	Costing ecosystem goods and services to create new markets for them. Subsidies to eco-tourism (market-based conservation schemes). Permits (tradable or not) for species extraction/use and mineral/abiotic extraction. Taxes and tax incentives for maintaining ecosystem structure and function.
Regulatory	Legal protection of endangered species and habitats. Sustainable ecosystem products (e.g. eco-labelling and green marketing). Import tariffs and subsidies that protect critical species and habitat in other countries and removal of export subsidies that lead to species and habitat loss within the country. Quotas for species, minerals and water extraction. Water, soil, and other abiotic quality standards and controls. Zoning requirements (e.g., limiting flood-plain development and building in sensitive areas).
Public investment	Integrated water management and adaptive management institutions and programmes. Livelihood-diversification programmes to reduce pressure on land, land-based resources, and biodiversity. State and local land reserves, including communal management of protected areas. Transition programmes that help species anticipate climate shifts. Removal of government investment policies that can have a negative impact on ecosystems. Targeted invasive species elimination and/or harvesting to restore current and future habitat for native ecosystems.
Information-based	Monitoring levels of ecosystems goods and services within a system. Seasonal, annual and decadal climate forecasts. Consulting model outputs and scenarios to construct narratives of possible future climate conditions (and the respective impacts and adaptation decisions). Improved monitoring of weather (e.g. through hand-held devices). Improved education and media reporting for understanding climate risk.
International co-operation	Debt for nature deals. Widespread distribution of alternative technologies and practices. International treaties and conventions, and bi- and multi-level agreements on cross-boundary resource management issues. International agreements outside the environmental sector that take ecosystem health into account.

Table 12: Policy options to increase marine ecosystem resilience

INSTRUMENT	POLICY OPTIONS
Market-based	Tradable fishing quotas (e.g. inter-transferable quotas). Fishing capacity buybacks. Polluter-paid schemes. Sustainable certification schemes. Tax incentives (or disincentives). Elimination of bad subsidies.
Regulatory	Fishing input controls. Fishing output controls. Legislation for the conservation of threatened species. Ecosystem and environmental standards (e.g., Marine Strategy Framework Directive). Integrated marine spatial planning.
Public investment	Sewage treatment facility. Investment in protected marine areas. Investment in resource-management research. Development of alternative livelihoods for fishing communities.
Information-based	Control surveillance and vessel monitoring system. Integrated assessment of marine ecosystems. Public education.
International co-operation	International agreement on fisheries, shipping, biodiversity and dumping. Regional fishery management organizations. International research collaboration and agreements on technological transfer.

such as through dam removal, may improve ecosystem resilience at the expense of humans whose livelihoods and security are dependent upon the current configuration of the ecosystem, such as through flood protection and energy production. The interaction of adaptation policies with mitigation measures also needs to be taken into account. For example, an adaptation policy that encourages reforestation can improve resilience by increasing biodiversity and habitat permeability, while also increasing mitigation benefits through additional capture and storage of carbon in the enhanced plant and soil matter. On the other hand, an adaptation policy that protects critical habitat for endangered species might prevent the development and commercialization of available renewable energy resources within the protected area (such as wind, geothermal and solar energy). The most successful adaptations policies are likely to include those that emphasize adaptive management and governance, research into social sciences, and developing incentives and disincentives for altering behaviour.

Increasing marine ecosystems resilience

Empirical observations and models indicate ocean conditions have been changing over the last 100 years and will most likely change more rapidly in the future. Major changes include ocean warming, acidification and expansion of oxygen minimum zones (the zone in which oxygen saturation in seawater in the ocean is at its lowest). Biological responses to these ocean changes have been observed in the marine biomes. Climate change could lead to high rates of species invasion in high latitude regions and local extinction along the tropics. Marine climate change affects primary productivity, species distribution and community and food-web structure, which have direct and indirect impacts on distribution and productivity of marine organisms. These have implications for the goods and services provided by the marine ecosystems to human societies.

Marine ecosystems are constantly changing as a result of changes in environmental conditions or human disturbance. In many cases, such changes are reversible, but only when environmental changes or disturbances are not too large. Ecosystem resilience is the magnitude of perturbation resulting from external human and environmental pressures that an ecosystem can withstand before such irreversible ecosystem changes occurs. Marine biodiversity, productivity and ecosystem functioning have already been altered substantially by human activities, (Millennium Ecosystem Assessment 2003). The main human impacts include overfishing, pollution and habitat destruction, which have increased ecosystem vulnerability and reduced its resilience, and exacerbated the impacts of climate change.

Improving ecosystem resilience must form an important element of climate-change adaptation policies. The main approach is to develop effective policy responses that regulate and manage human activities, and reduce other impacts on marine ecosystems. In doing so, it is important to understand the role of different socio-economic drivers in inducing pressures on the marine environment, leading to changes in the ecosystem states and impacts on the welfare of people and communities. A range of policy options may be applied, most of which aim to manage or reduce pressures from human activities on marine ecosystems (Table 12).

Reducing extreme weather event impacts

Economic losses and human suffering caused by extreme weather events such as floods, droughts and other climate-related events have escalated alarmingly in recent decades. Annual monetary losses from large-scale events have risen globally by an order of magnitude within four decades, an increase that cannot be fully explained by population or economic growth (Mills, 2009). According to the IPCC's Fourth Assessment Report, anthropogenic climate change is very likely to lead to increases in intensity and frequency of weather extremes throughout this century (IPCC, 2007). Low- and middle-income countries, and especially vulnerable people within these countries, suffer the most. Not only are there considerable differences in developed and developing countries in the immediate

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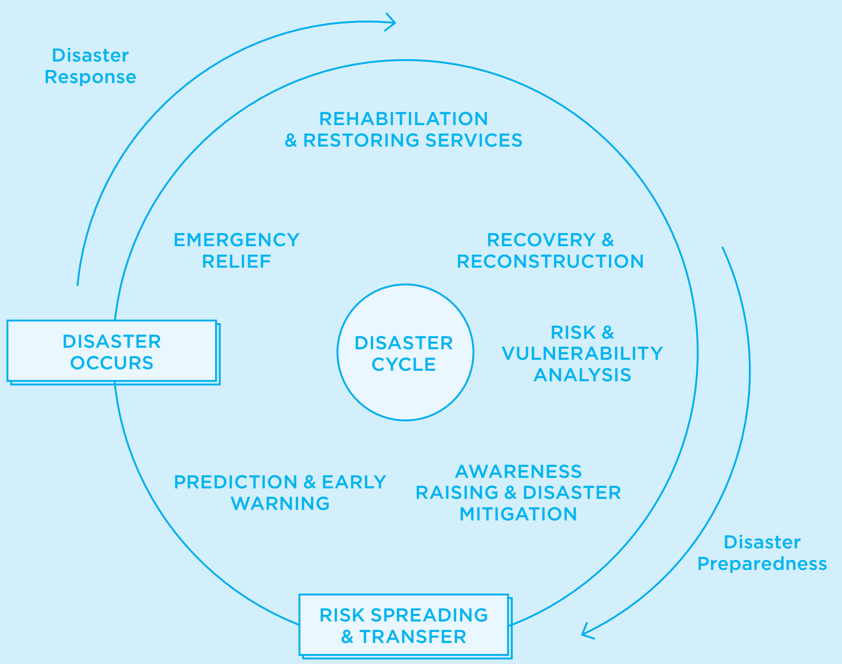
human and economic burden, but also in insurance cover. In the richest countries, about 30% of the losses are insured compared with only about 1% in low-income countries.

Many highly exposed developing countries do not have the means to raise capital to replace or repair damaged assets and restore livelihoods following major disasters, exacerbating the impacts of disaster shocks on poverty and development. Exposed countries often have to rely on donors to 'bail' them out after events, though only partial relief and reconstruction funding is usually made available and, even then, it often does not reach those most in need. Bilateral and multilateral donors currently allocate 98% of their disaster-management funds for relief and reconstruction and only 2% for proactive disaster risk management. Nonetheless, over the last few years, there has been a shift in international responses to natural disasters towards more proactive activity and upgrading the role of pre-disaster risk management. These efforts tie in with the distinction in climate-change policies between reactive (gradual coping with the consequences over time) and proactive climate adaptation (planned actions to prepare for climate change and reduce the associated adverse impacts) (Figure 3).

This figure shows preparedness (risk management) and response (responding to impacts)

Figure 3: Disaster management cycle



Policy options to reduce the various impacts of weather-related disasters and manage risk relate to assessing risk, reducing risk (prevention and preparedness), preparing for impacts, transferring and spreading it to a larger basis (risk financing) and, finally, responding to an event through reconstruction and rehabilitation (Table 13: See next page). Prevention and preparedness options reduce the losses, while insurance and other risk financing instruments lessen the variability of losses by spreading and pooling risks. The policy options cover short-term disaster-risk management (aimed at reducing current and near-future risk up to, for example, a decade ahead), to long-term climate adjustment (for example, land-use planning to respond to the risk of flooding) or both.

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Table 13: Policy options to reduce extreme weather event impacts

	POLICY OPTION	CATEGORY					TIME HORIZON	
		MARKET-BASED	REGULATORY	PUBLIC INVESTMENT	INFORMATION-BASED	INT'L CO-OPERATION	SHORT TERM (<10YRS)	LONG TERM (>10YRS)
Risk assessment	Hazard assessment				×		×	×
	Vulnerability assessment				×		×	
	Risk assessment						×	×
	Hazard monitoring & forecasting				×		×	×
Risk reduction	Physical & structural risk reduction works		×	×		×	×	×
	Land-use planning & building codes		×	×		×	×	×
	Economic incentives for proactive risk management	×			×	×	×	×
	Education, training & awareness raising				×	×	×	×
Preparedness	Early warning systems, communication systems			×	×	×	×	
	Contingency planning			×	×	×	×	
	Networks of emergency responders				×	×	×	
	Shelter facilities & evacuation plans		×	×	×	×	×	
Risk financing	Risk transfer	×	×	×	×	×	×	×
	Alternative risk transfer	×	×	×		×	×	×
	National and local reserve funds		×	×		×	×	×
	Calamity funds		×	×		×	×	
Response	Humanitarian assistance		×	×		×	×	
	Clean-up, temporary repairs & restoration of services		×	×		×	×	
	Damage assessment			×		×	×	
	Mobilization of recovery resources			×		×	×	
Reconstruction and rehabilitation	Rehabilitation/ reconstruction of damaged critical infrastructure		×	×		×	×	
	Revitalization for affected sectors			×	×	×	×	
	Macroeconomic & budget management			×	×	×	×	
	Incorporation of disaster mitigation in reconstruction activities		×	×	×	×	×	

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Climate plans need to be based on a careful assessment of the multi-dimensional impacts that a climate policy may have on human societies, the economy and the environment to ensure that the policy goals are reconciled with broader development objectives. The MCA4climate initiative proposes a framework for policymakers to use in evaluating the impacts of policy options across the different mitigation and adaptation themes and prioritizing them in a systematic, step-by-step way. That framework adopts a multi-criteria analysis (MCA) approach, a well-established policy-planning technique that is well suited to the complex challenges posed by climate change.

3 MCA4climate policy evaluation framework

Multi-criteria analysis and its rationale

Climate change will result not only in serious direct economic costs, but will also indirectly hamper economic growth prospects and inflict damage on humans and natural systems. Such social and environmental damages are difficult to evaluate, in particular because non-market impacts such as effects on human health, well-being and lifestyles, and ecological systems are often difficult to assess and express in monetary terms. Since the 1990s, the most common approach for investigating the costs of climate change and designing policies to combat it has been traditional cost-benefit analysis (CBA). This involves comparing the marginal costs of a mitigation or adaptation policy with the marginal benefits associated with the climate change that is avoided. CBA is well suited to pure investment projects, where future financial flows may be readily identified and predicted, but the approach has major limitations when applied to policies, including those designed to address climate change. The consequences of mitigation and adaptation policy are often not easily quantified in monetary terms and may, in any case, be extremely uncertain. Most CBA studies largely ignore non-market impacts, or externalities, and do not explicitly take uncertainty and risk into account. There are also fundamental concerns about inter-generational equity and, therefore, the appropriate discount rate to use in CBA analysis (see section 5).

In response to the shortcomings of the CBA approach, new approaches to policy assessment and decision-making tools have been developed. One such approach is multi-criteria analysis (MCA) [2] — the one adopted for the MCA4climate policy evaluation framework. MCA takes into account both monetary and non-monetary impacts and distinguishes between the multiple dimensions of the climate-change problem, ensuring transparency and accountability. MCA also helps determine preferences between policy options by reference to an explicit set of objectives that the decision-making body has identified and for which it has established measurable criteria to assess the extent to which the objectives have been achieved (UK DCLG, 2009). MCA techniques can be used to identify a single most preferred option or a mix of options, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities. It can be used both prospectively to evaluate policies before they are adopted and help decide which ones to choose, or retrospectively to verify whether a set of policies already adopted are appropriate. A key benefit of MCA is that it can handle disaggregated data on fundamental measures expressed in different units across relevant criteria, such as health effects and environmental impacts, and potentially over different time horizons and future scenarios. These data can be progressively aggregated in different ways to explore, for example, the impact of different views among stakeholder groups.

This approach is particularly well suited to the analysis of climate policies and climate-policy planning for several reasons. It can be applied to situations in which socio-economic, ecological, institutional and ethical perspectives need to be considered in an integrated manner. Its application is not limited to variables expressed only in monetary units. Morbidity and mortality, equity, environmental damage, catastrophic risks and uncertainty can also be taken into consideration in applying MCA, resulting in a more comprehensive analysis of all the costs and benefits of climate policies. Of course, where specific costs and benefits can be valued in monetary terms, either by direct observation of prices if appropriate or indirectly using generally accepted techniques, then these values can be used in combination with other criteria for which monetary valuations are not available. These characteristics make MCA particularly useful and more versatile for evaluating the cost of damages caused by climate change and extreme weather events which can have an array of market and non-market impacts across many sectors.

Another practical advantage of MCA is that it does not require results to be amalgamated into one final value, though this is possible. The impact of climate policies can be broken down into separate elements, for which data can be compiled and assessments made. These independent assessments can still provide valuable insights into overall costs and benefits. Disaggregation means that the approach is flexible enough to be applicable to different countries. Presenting a coherent overall picture to decision-makers requires judgements on scoring and weighting the different criteria, which can be a source of disagreement and controversy. However, with MCA, this process is carried out in a transparent manner, supporting stakeholder involvement and more democratic decision-making. The consequences of different scoring systems and weightings can be easily analyzed using sensitivity analysis (see the next section on case studies).

An important characteristic of MCA is the prominence given to the judgement of the policymaker (normally a team) in establishing objectives and criteria, choosing the techniques to measure them, deciding weights and in judging the contribution of each option to each performance criterion. But MCA provides a structured, open and transparent way of analyzing policies. In short, it leaves an audit trail (UK DCLG, 2009). The choices that the decision-making group make throughout the policy-evaluation process are open to analysis and to change if they are felt to be inappropriate. Moreover, the approach allows for direct participation by stakeholders in making those choices. Indeed, a fundamental strength of MCA is its emphasis on participative processes and collective judgement and decision-making. However, the contexts in which the methodology may be used

2 Throughout the project we use the generic term MCA to refer to an analysis of an issue which is based on multiple criteria. In the literature the term MCDA (multi-criteria decision analysis or aid) is also widely used highlighting that the analysis is generally carried out in the context of decision support (Belton and Stewart '2002', von Winterfeldt and Edwards; 1986). There are many specific approaches to MCA and the one used in our case studies develops and uses a multi-criteria value function. Strictly speaking, MCDA forms part of the overall MCA approach. In the literature on MCA the words criterion, attribute and objective are all used to refer to the factors which are to be taken into account in the analysis/decision (sometimes loosely, sometimes with a very specific local definition).

are such that there are likely to be very many possible ways forward and it is important to ensure that decisions are not biased, either as a consequence of an initially limited or inappropriate specification of options for evaluation, or a failure to see the process as an iterative one which can stimulate creativity and the design of new options. Subjectivity in this regard can be minimized through the participation of multiple experts and stakeholders.

Applying the MCA4climate policy evaluation framework

MCA is increasingly used by governments around the world to assist in evaluating projects and policies that have complex socio-economic and environmental impacts that are often hard to measure in monetary terms.[3] So far, it has rarely been used explicitly for evaluating climate policies. MCA4climate is the first major international initiative to develop an explicit MCA-based framework for climate-policy analysis at the strategic level.

The MCA4climate policy evaluation framework is intended to be used as a practical step-by-step tool for identifying and prioritizing mitigation and adaptation policies to be implemented as part of the process of formulating an overall climate strategy that is consistent with developmental goals. It ensures that all the different dimensions of climate policies, including those that cannot be easily measured in monetary terms, are taken into consideration. Importantly, it also facilitates the engagement of stakeholders in the policy-planning process. The intention is for the framework to be used prospectively, or in an *ex ante* way, to evaluate policies before they are adopted, though it is possible for it to be applied *ex post*.

The generic criteria tree

At the heart of this framework is a hierarchical criteria tree containing a set of generic criteria, against which climate-policy planners can evaluate proposed climate-policy actions and their potential contribution to a broad range of climate, environmental and socio-economic development objectives (Figure 4). This tree has been developed by UNEP through an intensive process of consultation carried out in close collaboration with a number of international experts involved in the MCA4climate initiative. The tree has evolved as the work on the initiative has progressed, especially in the light of the results of the case studies (see section 4). The version presented here is likely to change in the future as our experience with applying the framework expands and our understanding of the practical issues involved improves.

The generic tree has been built to ensure that each criterion is preferentially independent of the others, an important assumption of the MCA approach adopted. That is, the assessment of preference with

3 For example, it is a legal requirement for central governments in EU countries to use MCA in public procurement involving spending over a certain amount. The United Kingdom was one of the first countries to use MCA for different types of projects and policies, and the approach is now widely used across a wide range of central and local government activities.

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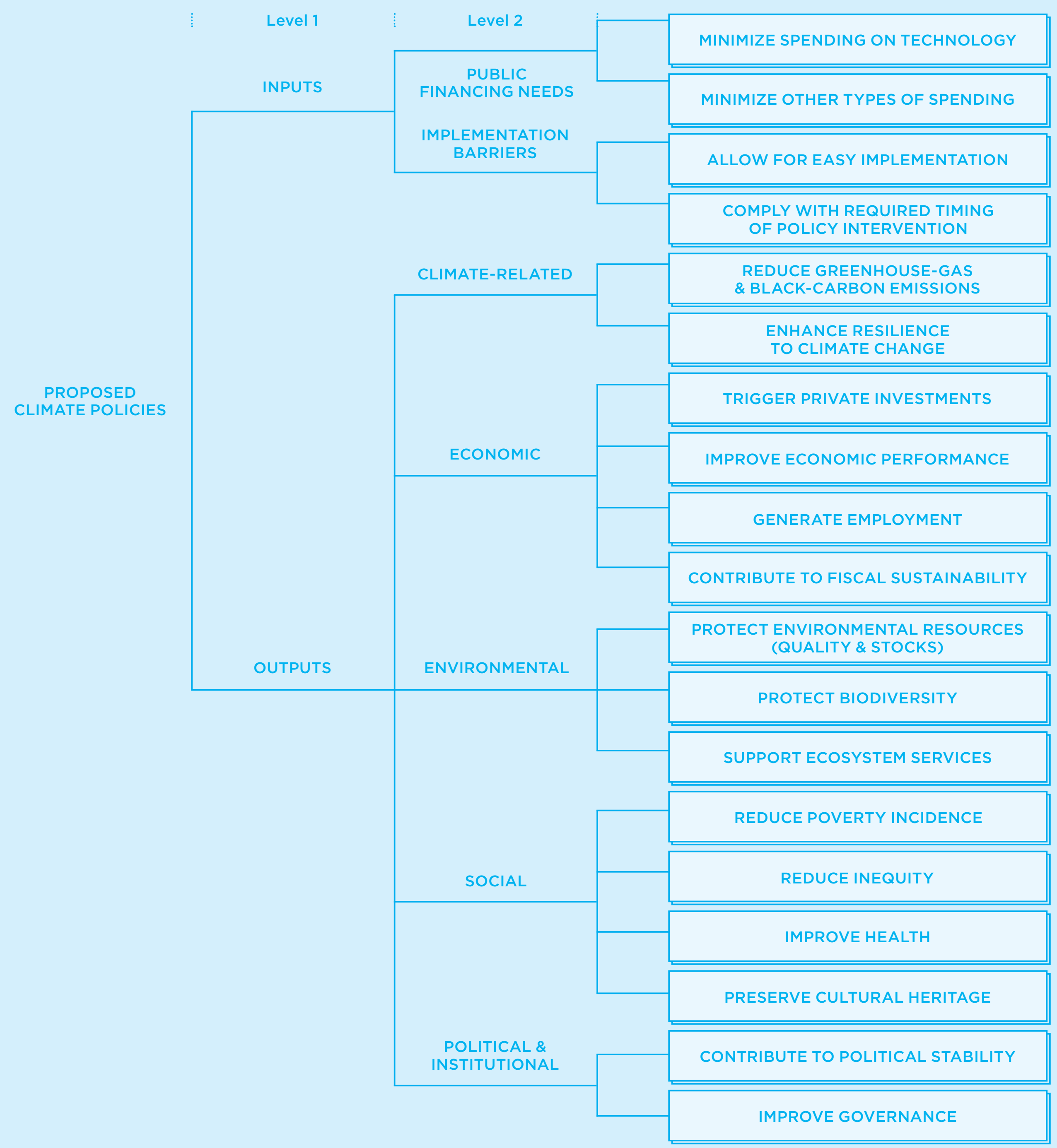
Figure 4: MCA4climate generic criteria tree



regard to the consequences of policy options against any one criterion is independent of the preference with regard to any other criterion. This is to ensure that the options can be scored on one criterion without knowing what the options' scores are on any other criteria. In practice, however, preferences with regard to the policy options themselves may not be independent, in that some policy options may score differently when implemented in combination with others. This issue is explored in the case study on Yemen (see section 4). In public decision-making, it is important to ensure that the set of criteria on which an analysis is based captures all relevant concerns; that is, they do not reflect a restricted or partisan perspective on the issue, which might lead to a biased evaluation. The involvement of theme experts in the MCA4climate initiative has ensured that the generic criteria tree presents a comprehensive framework for the evaluation of options, based on a range of views about all relevant considerations. The structure has been debated, tested and refined through the illustrative case studies described in this report. A key benefit of the generic tree is that decision makers are alerted to all potentially relevant impacts in any specific context without the need to engage in a lengthy problem-structuring process or to have direct access to the wide range of expert knowledge underpinning this initiative. The generic criteria tree contains three levels:

- 1st level: There are two criteria — inputs to (or efforts required) and outputs (or possible impacts) of proposed policy options.
- 2nd level: There are seven criteria at this level, two of which relate to the impact on the input side (public financing needs and implementation barriers) and five to impacts on the output side (climate-related, economic — including fiscal, other environmental, social, and political-institutional dimensions of development). The impacts can be either positive or negative.
- 3rd level: There are a total of 19 criteria at this level — four on the input side (which include monetary and non-monetary costs that need to be met for effective policy action) and 15 on the output side (which relate to specific impacts on society, the economy and the environment).

The 3rd-level criteria evaluate the extent to which policy options meet the following objectives:

- Minimize spending on technology: this refers to the financing needs required from the public purse in order to support a particular mix of technologies. This may refer, for instance, to the difference between the market price and the guaranteed electricity price in the case of a renewable feed-in tariff

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mitigation measure, or to the capital and operating expenditures relating to the construction and maintenance of a bridge in the case of infrastructure adaptation measures.
- Minimize other types of spending: financing needs required from the public purse in order to support a climate-policy measure other than the technology itself. This may refer, for example, to the cost of implementing, enforcing and monitoring a policy, such as energy-efficiency standards.
- Allow for easy implementation: the suitability of existing regulatory frameworks and the changes in institutional arrangements required for pursuing the climate-policy option being put forward (for example, changes in law and governmental ordinances required). It may also relate to ownership issues, such as clearly defined land-property rights, social acceptability or stakeholder engagement that could condition the effectiveness and fairness of some policy measures.
- Comply with required timing of policy intervention: this refers to the time necessary for a proposed policy option to become effective (which may vary from a few months to five to ten years or even longer) and how well that fits in with the need to respond to the threat posed by climate change.
- Reduce greenhouse-gas and black-carbon emissions: the extent to which a climate-policy option affects the annual rate and cumulative emissions of human-made greenhouse gases released in the atmosphere. It typically represents the primary objective of mitigation action, though it may be important (as a side effect) under some adaptation options as well.
- Enhance resilience to climate change: how a policy builds (or erodes) the ability of social-economic and ecological systems to persist in the face of climate change, as well as to transform them into new and more desirable configurations when required. It typically represents the primary objective of adaptation action.
- Trigger private investments: the potential of a policy to leverage investments from the private sector. This may be further determined at the macroeconomic, industry or sectoral level. Indicators to measure the level of private investment triggered may also be expressed in terms of net investment costs (for example, the difference between investment costs and energy savings over time for an energy-efficiency policy).
- Improve economic performance: economic output, competitiveness and technological change effects arising from climate policy. This may refer to a specific industry or region, as well as to the economy at the national level. In addition, competitiveness impacts may relate to price

competitiveness (such as changes in productivity) and non-price competitiveness (such as changes in trade flows).

- Generate employment: direct job-creation effects of a policy on a specific industry or region plus indirect knock-on effects throughout the rest of the economy. Distributional employment impacts across categories of population could be also considered.
- Contribute to fiscal sustainability: the effect of climate-policy actions on the primary and secondary public accounts, including both government revenues and government expenditures.
- Protect environmental resources: this covers policy-induced impacts on water, land and air quality and the corresponding natural resource stocks (where applicable).
- Protect biodiversity: biological diversity includes here the variety of living organisms, the genetic differences among them and the diversity of ecosystems that they inhabit.
- Support ecosystem services: this criterion refers to the services of natural ecosystems that humans benefit from. These services can be classified into four broad groups: provisioning services, regulatory services, supporting services and cultural services. [4]
- Reduce poverty incidence: impacts of a climate policy on the incidence of income poverty, access poverty and empowerment or social fabric issues. For example, impacts may refer to the number of people below an income-poverty line. The incidence of access poverty may relate to the number of people without access to energy, finance, water, land and other resources.
- Reduce inequity: climate policy-induced changes in the systematic disparities between groups of population (intra-generational) or generations (inter-generational) in terms of income and access to resources or services. These refer to inequity considerations other than employment and health distributional impacts included in the other criteria.
- Improve health: human-health aspects directly or indirectly affected by climate policy concerning nutrition, vector-borne diseases, water and air-related risks and diseases, and the overall health of populations. It also includes distributional health impacts across different types of population or households.
- Preserve cultural heritage: this refers to the impacts of climate policy on cultural assets. In the case of adaptation, cultural assets at risk due to climate change can be protected (though mal-adaptation may increase these risks). In the case of mitigation, cultural assets may be either endangered (for example, the effect of building a wind farm on culturally valuable sites) or may be further preserved (for example, avoiding deforestation in forests associated with important spiritual or cultural values). Cultural heritage may refer to tangible cultural heritage consisting of movable assets (such as paintings, sculptures and manuscripts) and immovable assets (such as monuments and archaeological sites), as well as intangible cultural heritage (such as oral traditions, performing arts and rituals).
- Contribute to political stability: policy impacts on changes in conflict and violence risks related to water-stress, food security and migration, as well as on energy security. These risks may be avoided but also multiplied depending on how climate-change impacts are addressed. Energy security refers to changes in the vulnerability of a country's energy supply to external factors beyond its control. Aspects that could be considered here include the growing dependence on imported fuels from monopolistic sources or produced in or transiting unstable countries, as well as the impacts of extreme weather events and natural disasters.
- Improve governance: policy impacts on national or local governance structures, including institutional setups and regulatory frameworks. For instance, organizing action at the community-level to help manage and adapt to climate change can improve local governance in general, which could bring benefits in dealing with other issues.

In practice, the generic tree can be extended to lower levels to allow a more detailed analysis of policy options corresponding to different themes. This is explored in two of the case studies set out in section 4.

Based on the generic criteria tree, we developed sets of indicators corresponding to each of the 12 policy themes — four covering mitigation and eight covering adaptation. These indicators have been identified to provide practical measures of performance of policy options against the 3rd-level criteria. In practice, the indicators to be used would draw on these generic sets (though additional indicators might be selected depending on national or local circumstances). The indicators are expressed in monetary or non-monetary terms; in the case of the latter, they are quantitative or qualitative. Some indicators are applied across different themes. For each theme-specific indicator, general recommendations on the most appropriate methods of assessment and sources of data have been drawn up. These recommendations take account of the guiding principles and practical recommendations on how to address a number of critical issues for climate-policy analysis (set out in section 5). An example of some of the main proposed indicators for three themes — two on mitigation (energy efficiency and CCS) and one on

4 Based on the 2005 Millennium Ecosystem Assessment (UNEP, 2005). Detailed definition and descriptions can be found at: www.millenniumassessment.org/documents/document.300.aspx.pdf

Table 14: 3rd-level criteria and indicators for improving energy efficiency and conserving energy

CRITERION	MAIN INDICATORS
Minimize spending on technology	Overall cost of energy-efficiency improvement policies (including investments in innovation and technical capacity, and subsidies and tax exemptions/deductions)
Minimize other types of spending	Implementation, administration, enforcement and programme costs; as well as investments in training, evaluation and expansion of consumer education and market-bases initiatives
Allow for easy implementation	Quality of institutions, including number and size of institutes/ organisations involved in policy implementation, execution and monitoring
Comply with required timing of policy intervention	Time required for designing energy efficiency policies and time taken by policies to be effective
Reduce greenhouse-gases and black-carbon emissions	Emission reduction in percentage reduction of greenhouse gases (& black carbon if relevant) compared to a business as usual
Enhance resilience to climate change	Not applicable
Trigger private investments	Whether businesses/households invest in energy efficient equipment and target groups (e.g. number of households that have implemented energy saving measures)
Improve economic performance	Changes in the energy use in industry and households; Costs of measures (e.g. cost per tonne of CO_2 emissions avoided) and share of energy costs in overall costs of industry and household spending
Generate employment	Number of jobs created in energy efficiency services and number of technical staff trained; as well as number of jobs created in other sectors linked to those sectors for which energy efficiency improvements occurred
Contribute to fiscal sustainability	Development of public investment over time, including projected (and realised) public spending on energy-efficiency policies, and changes in government revenue from energy taxes
Protect environmental resources (quality and stocks)	Indoor air quality indicators such as the use of appropriate fuels, pollution control and exposure reduction
Protect biodiversity	Changes in number of species if applicable
Support ecosystem services	Not applicable
Reduce poverty incidence	Basic energy needs covered (e.g. % of households with access to electricity and other forms of commercial energy) and changes in household energy use (e.g. % of household income spent on fuel and electricity; % of households that rely on traditional cooking methods)
Reduce inequity	The distribution of number of people with access to energy across different types, including number of households connected to a local or centralized electricity network); and household energy use across income groups
Improve health	Environmental conditions of the housing properties, including share of households in neighbourhoods with above average pollution rate and % of households that cook inside the house
Preserve cultural heritage	Not applicable
Contribute to political stability	Reduce dependency on energy imports (e.g. % share of commercial fuels exported); physical reserves of energy
Improve governance	Existing mechanisms to fund energy efficiency implementation and improve energy efficiency governance (e.g. stimulus funding, general appropriations from government budgets)

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adaptation (health) — are given in Table 14, Table 15 (See next page) and Table 16 (See next page). More details about the indicators and the recommended methods of assessment for each of the themes can be found in the individual theme reports, which are available at www.mca4climate.info.

Steps in applying the framework

The full process of applying the MCA4climate policy evaluation framework involves seven main steps, summarised in Box 1. These steps are demonstrated in the case studies in section 4. Once the context has been established, including clarifying the climate and other policy objectives, the key steps are to: identify policy options or policy portfolios to be evaluated; agree on the criteria and indicators starting from those already suggested under this framework; agree on scenarios, the timeline of the analysis and methods of assessment (drawing on the guiding principles of the MCA4climate initiative — see section 5); score the different options against the agreed criteria; weight the criteria to reflect different stakeholder perspectives and priorities, and using these values together with the scores to, derive a measure of aggregate performance for each option at higher levels of the criteria tree; and, finally, explore these initial results through sensitivity analyses.

The application of the framework up to the fifth step only can provide very useful insights into how each policy option performs and may be sufficient to inform decision-making, without attempting to prioritize those options in an explicit way. The value of this level of analysis is illustrated in the case studies. To proceed beyond this step

Table 15: 3rd-level criteria and indicators for encouraging carbon capture and storage

CRITERION	MAIN INDICATORS
Minimize spending on technology	Investment and operating costs
Minimize other types of spending	Costs of assessments. Revenue generating potential for enhanced oil recovery
Allow for easy implementation	Presence of oil and gas industry or mining law for deep underground. Number of specialized workers; existence of mandated competent authority
Comply with required timing of policy intervention	Time needed to issue the respective laws/regulations
Reduce greenhouse-gas and black-carbon emissions	Tonnes of CO_2 emissions avoided
Enhance resilience to climate change	Not applicable
Trigger private investments	Ratio of public/private investment in the technology
Improve economic performance	CCS-related turnover
Generate employment	Amount of jobs created as a consequence of CCS
Contribute to fiscal sustainability	Projected (and realized) public spending on CCS. Projected (and realized) tax income resulting from CCS
Protect environmental resources	Emission reduction of SOx, NOx, particulate matter and mercury. Safety risk of storage operations (probability x impact)
Protect biodiversity	Location of storage potential in nature reserves
Support ecosystem services	Dependence on groundwater resources for human consumption. Projected leakage rate into groundwater resources for human consumption under legislative scenarios
Reduce poverty incidence	Not applicable
Reduce inequity	Inclusion of appropriate stakeholder engagement guidelines or obligations in CCS legal framework
Improve health	Changes in health expenditures. Incidence of respiratory diseases. Mortality or DALYs (disability-adjusted life years)
Preserve cultural heritage	Location of cultural assets close to storage potential
Contribute to political stability	Dependence on fossil fuels (in particular coal). Additional fuel use (GJ)/reduced power supply as a consequence of CCS
Improve governance	Community engagement and strengthening of institutions

Table 16: 3rd-level criteria and indicators for reducing human health impacts and risks

CRITERION	MAIN INDICATORS
Minimize spending on technology	Capital and operating expenditures (monetary)
Minimize other types of spending	Spending on strengthening heath systems and assessing vulnerability to climate impacts (monetary)
Allow for easy implementation	Required institutional set-up (number of organizational changes)
Comply with required timing of policy intervention	Time horizon of implementation and time taken to be effective (time)
Reduce greenhouse-gases and black-carbon emissions	Reduced carbon footprint of health services (CO_2-equivalent emissions)
Enhance resilience to climate change	Increase in the number and quality of health-related measures (number & qualitative description or measure).
Trigger private investments	Investments in primary healthcare and in hospitals (monetary)
Improve economic performance	Increase in economic output (economy-wide production indices) and economic productivity (input/output ratios)
Generate employment	Reduction in unemployment due to ill-health (number)
Contribute to fiscal sustainability	Health sector jobs (number)
Protect environmental resources	Reduction in chemical spraying (amount of chemicals per hectare per type of chemical)
Protect biodiversity	New drug treatments developed (number by type)
Support ecosystem services	Maintenance of healthy environment (quality of air, water and soil)
Reduce poverty incidence	Increase in household access to healthcare services (% of population with access) and household spending on healthcare services (monetary)
Reduce inequity	Increase in household access to healthcare services and spending by age, sex and socio-economic group (distributional)
Improve health	Reduced mortality and morbidity rates attributable to climate change (number)
Preserve heritage	Preservation of lifestyle and diet (qualitative)
Contribute to political stability	Avoidance of popular unrest (number and seriousness of riots, strikes and demonstrations)
Improve governance	Establishment of publicly accountable institutions (accountability and transparency)

calls for judgement in determining the weights to be assigned to each criterion, reflecting the prioritization of the impact associated with each criterion (step 6). This underpins the calculation of aggregate scores at higher levels of the criteria tree in order to come up with a definitive comparative evaluation of all of the options and enable the exploration of the outcomes through sensitivity analysis (step 7). [5]

Box 1: Key steps in implementing the MCA4climate policy evaluation framework

1 *Establish the context*
Clarify climate policy goals for mitigation and/or adaptation. Identify the decision makers and main stakeholders. Consider the main national socio-economic, political, institutional and environmental circumstances .

2 *Identify the options to be evaluated*
Draw up a set of mitigation and adaptation policy options (these can be either single policy actions formulated at different levels of detail or portfolio or mix of policy options).

3 *Agree on criteria and indicators*
Consider at what level of criteria the analysis should occur and whether it is necessary to modify the suggested generic or theme-specific criteria and indicators

4 *Agree on scenarios, timeline of analysis and methods of assessment*
Establish the climate and socio-economic scenarios for the future that are to be considered in the analysis. Agree on dynamics and time-frames, short-term, medium-term or long term. Agree on the methods of assessment to be deployed.

5 *Score the different options*
Asses the performance of each policy option against all of the criteria using the chosen assessment methods. Based on this assessment, score the options against the criteria (in each scenario if different scenarios are explicitly modelled).

6 *Weight the different criteria and calculate an overall input and output values for each policy option*
Assign weights to each criterion. Calculate aggregate weighted scores for each option at each level in the hierarchy, (keeping the input group separated from the output groups). Calculate overall weighted scores on the input side and on the output side

7 *Examine and test the results* [6]
Examine the results, comparing the performance profiles of options at each level of the criteria tree to identify dominating or dominated options (i.e. those with the highest and lowest scores) and to highlight particular strengths and weaknesses. Compare pairs or combinations of options if applicable. Carry out sensitivity analysis by altering weights and/or scores and examine how those changes affects relative rankings of policy options. Compare the performance of options across different scenarios if explicitly modelled. In light of the results, consider new policy options

5 The analysis up to and including step 5 can be done manually, although an overview of the performance of options is facilitated by formal visual presentations of the scores. The calculation of aggregate scores and associated sensitivity analyses can be done using a spreadsheet, but is greatly assisted by the use of customized decision support tools. For example, in our case studies we have used the V.I.S.A (Visual Interactive Sensitivity Analysis) software tool (please see www.visadecisions.com).

Scoring and weighting

The process of scoring options against a specified criterion perceived their 'added value' relative to a defined reference point. There are many different ways of scoring options which vary according to the amount of work involved and to the extent to which the outcomes are justifiable to a public audience, explainable and replicable. Subjectivity in scoring can be minimized by: [7]

› Reference to objectively measurable quantities.
› The use of individuals with expertise in both the concept under evaluation (e.g. health impact) and the context of application (for example, in a specific region).
› The specification or construction of an appropriate scale defined in terms of performance against one or more objectively measurable criteria.
› A solid stakeholder engagement process.
› A multi-stage process in which initial scoring of options is carried out independently by a number of experts, forming the basis for discussion.
› Use of an experienced facilitator who supports and challenges those responsible for scoring the options.

The MCA4climate policy evaluation framework does not impose any particular method for scoring. The case studies described in the next section illustrate one possible approach — relative

6 The notion of dominance is an important one in MCA. Option A dominates Option B if it performs at least as well on all criteria and better on one or more criteria. This means that whatever weights are assigned to the criteria, A will always be preferred to B.' Amend all other footnote numbers accordingly.
7 An overview of approaches to scoring can be found in chapter 5 of Belton and Stewart (2005). A good example of a process which is aligned with a number of these characteristics is the CORWM evaluation of UK options for handling radioactive wastes (www.corwm.decc.gov.uk) documented in Catalyze (2006, 2006a).

preference scales (more specifically, direct rating on a 0 to 100 'locally defined' scale was adopted). But, given the illustrative nature of the cases, this was driven by a desire to minimise the workload rather than maximise accountability.

Relative preference scales are simply scales anchored at their ends by the most and least preferred options on a specific criterion. For example, the preferred option is assigned a preference score of 100, and the least attractive is given a score of zero. Scores are assigned to the remaining options so that differences in the numbers represent differences in strength of preference. Modelling can be used for some criteria to help convert the impacts of climate-policy options into scores that are comparable.

If the number of criteria is small and a decision can be made directly from the scoring information obtained, the evaluation may not even require formal weighting and aggregation techniques. However, where this is not the case, the criteria will need to be weighted. As with scoring there are many different approaches to weighting criteria and it is important to ensure that the process used is transparent and robust. Criteria weights reflect the relative worth of value added on different criteria; it is important to remember that this is defined in terms of the specific scales used to define those criteria in the context of a specific analysis, not as vaguely expressed generic priorities. In particular the meaning of the weights and the associated elicitation process must be well understood by those whose judgements the weights reflect, who should be able to explain and justify the outcomes.

As with scoring, this can be achieved by a sound, facilitated, multi-stage elicitation process, involving a number of individuals representing the same stakeholder perspective and forming the basis for discussion which seeks to illuminate and reconcile differences. Weighting has a significant impact on the aggregated scores for each option. A sound and commonly used method, adopted in all three case studies, is swing weighting, which is based on comparisons of differences in the same way as for scoring using relative preference scales. This method is used to determine the weights across the bottom level of the criteria tree. This approach first identifies the criterion which gives the greatest 'added value' in moving from the least preferred (with a score of zero) to the most preferred (with a score of 100) position on a particular criterion. Given the large number of criteria (19 at the third level), it may be helpful to use a paired-comparison process to first determine the order of criteria, i.e. compare criteria two at a time for their preference swings, always retaining the one with the more highly valued swing to be compared to a new criterion. Once they have been ordered, a weight of 1 is assigned to the criterion that comes out on top, which becomes the standard to which all the others are compared.

The next step is to determine the relative added value associated with each of the other criteria, usually identifying the

next greatest and assigning a weight (with value less than 1) which reflects the relative value of 100 points. When all weights have been determined the values are normalized to sum to 1 (simply as a mechanism to keep the aggregate scores at all levels of the tree within the range 0 to 100). This stage of the analysis is necessarily subjective in that there is no 'value-free' or absolute statement of the relative significance of impacts as diverse as those captured in the MCA4climate criteria tree. It is to be expected that different stakeholder groups would prioritize outcomes differently and one of the strengths of MCA is to enable the exploration of the consequences of those differences. Yet, the public acceptability of the process will be influenced strongly by the consultation process involving different stakeholders or their representatives.

Depending on the extent to which involved parties can be expected to have similar priorities, a 'sharing' or 'comparing' approach to determining weights may be more appropriate. A sharing approach seeks to attain an agreed set of weights, possibly starting with the assessment of individual values then seeking to reconcile differences through a process of discussion. A comparing approach accepts that different individuals, or sub-groups of stakeholders, will have different priorities and only seeks agreement with the sub-group.
The consequences of differences between groups can be explored through the use of sensitivity analysis, with a view to finding options which perform well from the perspective of all groups. Even if it proves difficult to reach consensus, explicit awareness of the different weight sets and their consequences can facilitate the further search for an acceptable compromise.

The final step in the process of applying the MCA4climate policy evaluation framework is to examine the resulting aggregate values that are derived by applying the weights to the set of scores for each of the policy options. This should normally be accompanied by sensitivity analysis to gain an understanding of the extent to which the results depend on the different scores and weights. In many cases, the outcomes are relatively insensitive to changes in the scoring and weightings, which gives confidence that the priorities that have been established are robust. The process of comparing options may also lead to the identification of a new or slightly modified option, which might offer many of the benefits of the most beneficial option, but at lower cost. Sometimes this is accomplished by reducing the benefits, and thus the cost, on those criteria that do not carry much weight. Reducing the cost in this way may more than compensate for the loss of benefit, giving an option that is quite beneficial without being too costly. If new options are generated in this way, they should be added to the set of options and evaluated along with the others in a second run. Several iterations of the scoring and weighting procedures may be necessary to arrive at a final decision.

Other techniques for scoring and weighting criteria than those described above are possible, which can lead to different overall results, for a number of reasons. Firstly, although the underlying MCA model is a mathematically simple weighted sum, the meaning of its components (i.e. the scores and weights) are precisely defined and inter-related, as outlined above. If the processes used to determine those scores and weights are not properly specified and aligned, then inconsistencies can arise. Secondly, if the decision-maker is unsure of their values or has not fully understood what is asked, then different ways of questioning (or even the same approach at different times) can elicit different responses. These potential pitfalls underline the importance of sound processes.

However, it is important to note the outcome of any intervention using the MCA4climate policy evaluation framework — as with any MCA approach — is determined as much by the process and the philosophical stance taken by the participants as by the particular decision-making or analytical tools that are used. In other words, we fully acknowledge that the analysis undertaken is not value-free and, although the aim of MCA is to make those values explicit and transparent, the participants in the decision-making process still have to reach agreement. As with any analysis, subversion (intentional or otherwise) is possible if not held in check through the critical oversight by others. As outlined above, the approach taken to decision-making on climate policymaking is crucial, particularly where there is a broad range of stakeholders. That approach has to enable multiple values and interests to be taken into consideration, as well as help understand the different underlying conflicts and trade-offs that could be associated with a particular set of policy choices.

The application of the MCA4climate policy evaluation framework in practice requires a certain level of organization and co-ordination by the private sector, civil society, local governments and other groups at the national or regional level. Where the decision-making process is highly hierarchical or where climate-policy action is the domain of a particular executive power, multiple stakeholder participation may not be possible. Nonetheless, the results of applying the framework can still be of value, especially where they are made available for public consultation.

4 Case studies

In order to test the MCA4climate policy evaluation framework and demonstrate that it works, we applied the framework in three separate case studies: Mumbai (in India), South Africa and the Sana'a Basin (in Yemen). They also provided an opportunity to apply the guiding principles of climate-policy planning in a real-world setting. The results of these case studies helped to refine the framework, particularly the criteria, and provided important insights into the way it can best be applied. Because of resource and time constraints, each case study focused on a particular theme, and involved a core two-day workshop at the UNEP offices in Paris.

Each study looked at different types of policy options — single policies in Mumbai, portfolios of policies in the Sana'a Basin in Yemen and broad scenarios in South Africa. The choice of case studies was guided by the aim of demonstrating the adaptability of the framework to different situations. These case studies pave the way for applying the framework in a full-scale pilot project.

4 Case studies: Mumbai

The purpose of this case study was to illustrate the evaluation of climate adaptation policy options to increase infrastructure resilience in Mumbai — an Indian city covering more than 480 square kilometres with a population of 12 million (including the suburbs). [8] Mumbai is prone to severe flooding, which now occurs almost annually — the consequence of the climate and the way the city has developed. Climate change is expected to increase the severity and frequency of flooding. Strengthening the city's infrastructure to better resist flood risks is difficult for several reasons: land is scarce, making it hard to impose a zoning policy that allows construction only outside flood-prone areas; the population is still growing rapidly, increasing demand on transportation, electricity and water services; most of the population still lives in informal settlements; institutions are weak and land tenure uncertain, making land-use or building regulations difficult to enforce; and the city is politically unstable, with latent conflicts between different population groups.

Criteria and policy options

The first step in the exercise was to identify sub-sets of criteria relevant to the theme of infrastructure resilience for each of the 3rd-level criteria in the generic criteria tree. [9] This was achieved through wide-ranging discussion within the group of participants. The results are shown in Figure 5 (See next page). Because of time constraints and since the purpose of the exercise was to demonstrate the applicability of the MCA4climate framework, operational indicators were not specified and the evaluation of the options was based solely on the criteria.

The next step was to identify a set of policy options to be evaluated drawn from a larger set of possible options. The final set of five options was selected to represent a broad range of options that could be expected to have impacts that could be measured using the infrastructure theme-specific criteria (Table 17).

Scoring the options

To simplify scoring, the approach described in section 3, involving direct rating of options against a 0 to 100 'locally defined' scale, was adopted. In other words, the scale was defined for each infrastructure theme-specific criterion by the 'best' and 'worst' of the five options, which were positioned at 100 (best) and 0 (worst) on the scale. The other options were then scored according to their performance relative to these two reference points, the position of each being determined by the relative difference between it and the reference points. Thus, scoring option X at 50 means that the value-added by moving from the worst option to option X (50 points) is judged to be

8 An OECD report on Yemen was used as the starting point for this case study (Hallegatte et al. 2010).
9 This process contributed to the set of indicators that were still being developed for the increasing infrastructure resilience theme, as well as to the development of the generic criteria tree. At the time of the workshop, an earlier version of the generic criteria tree was used for this analysis.

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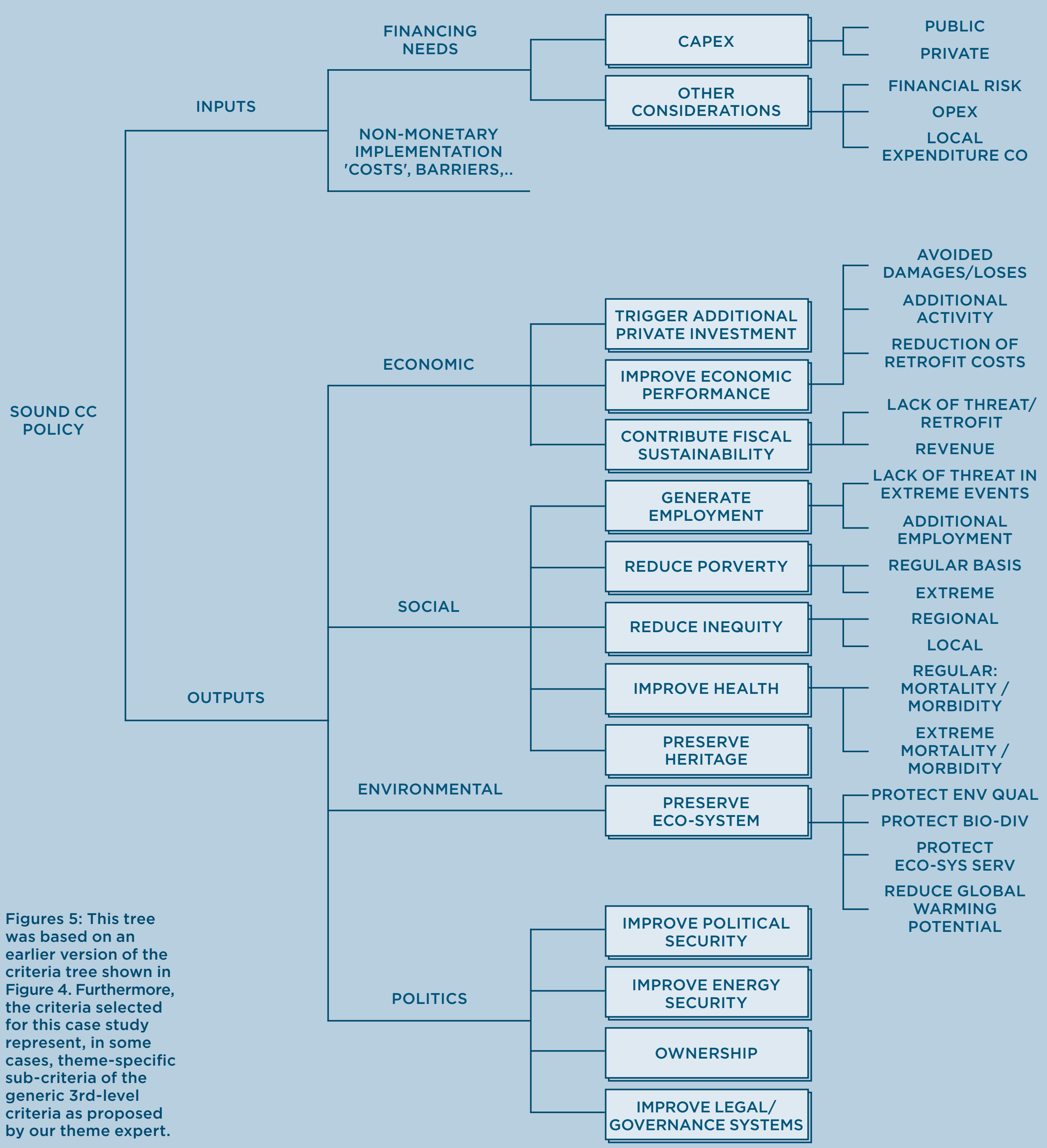
equivalent to the value added in moving from option X to the best option. [10] The results are shown graphically in Figures 6 to 10 (See pages 71–73) for the profiles of each of the five policy options considered in this case study. Some patterns emerge from this analysis, which confirm the complementary nature of the policy options selected for analysis:

Table 17: Policy options to increase infrastructure resilience in Mumbai

POLICY	INSTRUMENT	DESCRIPTION
PT: Public Transport	Infrastructure development would be funded through a combination of taxation and public investment.	Build the planned transport link on stilts as opposed to underground (which represents a decrease in financial cost and an increase in co-cost like noise and views). Significant new infrastructure would be required to complete the project, which would bring the opportunity to link to the wider transport network (monorail and roads) creating better city-wide mobility.
BC: Building Codes	Command and control type regulatory instrument.	Amend existing building regulations and introduce new regulations where necessary to ensure that in 20 years' time all floodplain buildings are on stilts, and earthquake-proof. Unauthorized colonies must be prevented and regulations enforced.
WS: Warning Systems and Emergency Response	A combination of public investments (e.g. setting up of new centres and services) and information-based instruments (targeted education and communication).	The formation and coordination of a 'disaster management' cell – including government, emergency services, logistics and weather-forecast services. It would also involve the building of designated safe shelters, as well as targeted communication and education to relevant sectors of the population.
I: Insurance	Public investment since this is a government financed scheme (although there is the potential to support this through taxation).	A government scheme aimed at low-income households and the informal sector. The insurance would be compulsory. The aim of this policy option is to achieve 80% coverage within ten years.
ER: Enforced Retreat	A command and control regulatory instrument.	The definition of high-risk priority areas, the enforced movement of people living in those areas, the location and development of alternative settlements and the restoration of vacated areas. The target would be up households and small businesses. Although this would be government supported policy, the opportunity for public/private partnerships would be promoted in the development of new settlements.

10 More details about the software and how it works can be found at: www.visadecisions.com

Figure 5: Mumbai case study criteria tree



Figures 5: This tree was based on an earlier version of the criteria tree shown in Figure 4. Furthermore, the criteria selected for this case study represent, in some cases, theme-specific sub-criteria of the generic 3rd-level criteria as proposed by our theme expert.

Figure 6: Scoring profile for option Public Transport (PT)

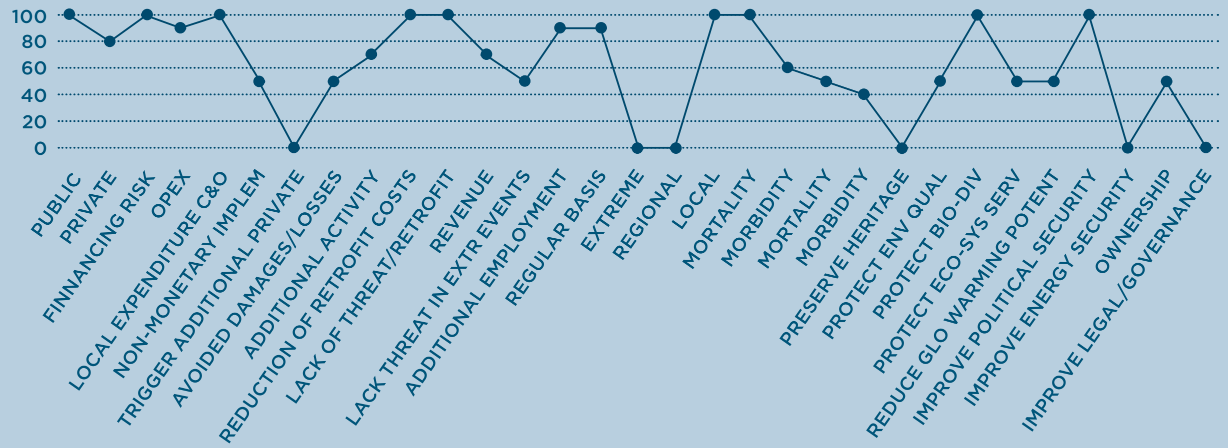
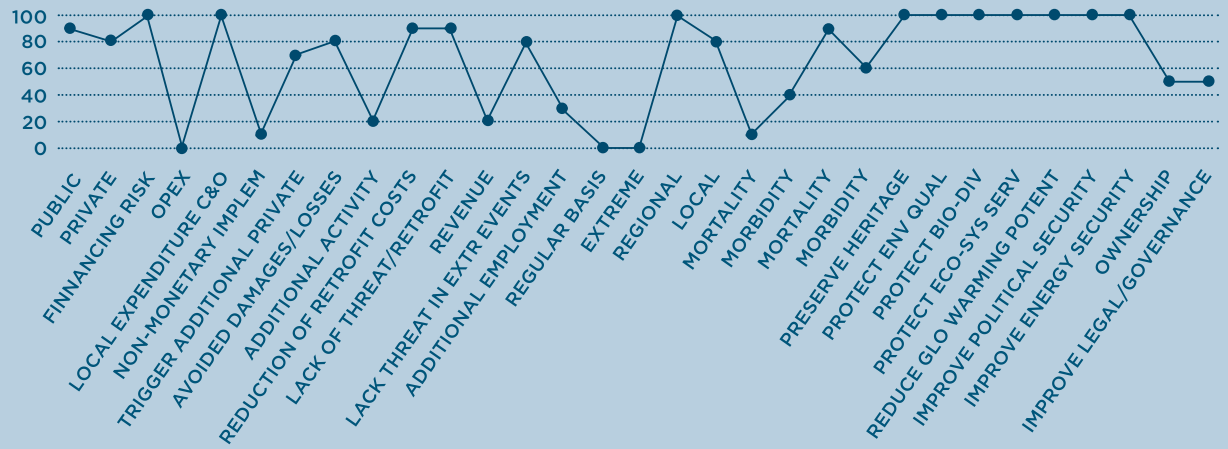


Figure 7: Scoring profile for option Building Codes (BC)



Figures 6–10: The scale was defined for each infrastructure theme-specific criterion by the 'best' and 'worst' of the five options, which were positioned at 100 (best) and 0 (worst) on the scale.

› Against the input criteria, the Retreat option clearly fares badly compared with the other options for financial inputs, as this option would obviously be very expensive to implement. Against the output criteria, the performance of this option is extreme in that it is, or is close to, the best or the worst of the options considered on the majority of the criteria: it performs particularly badly against the environmental criteria but is the best option on some other criteria, notably economic impacts.

Figure 8: Scoring profile for option Warning Systems and Emergency Response (WS)

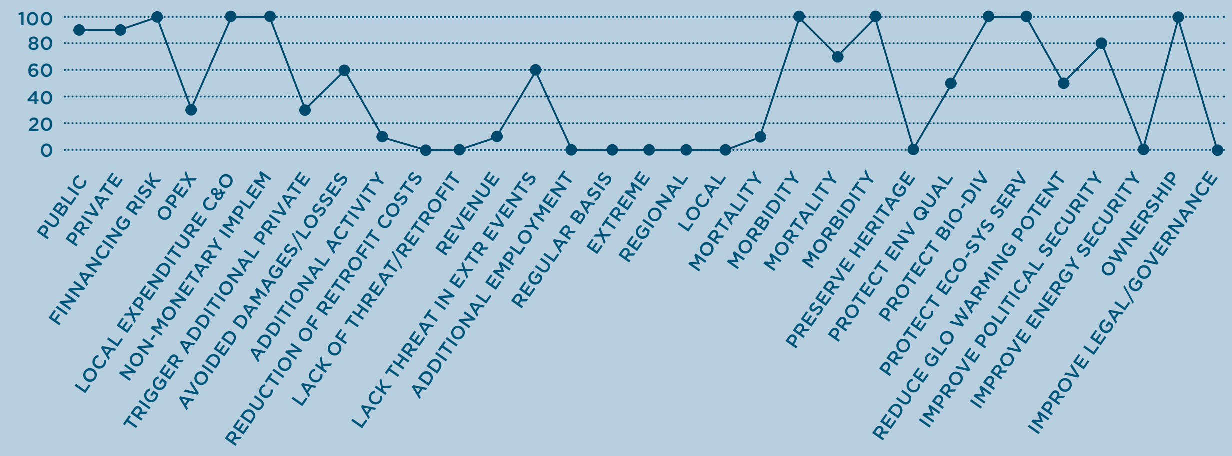
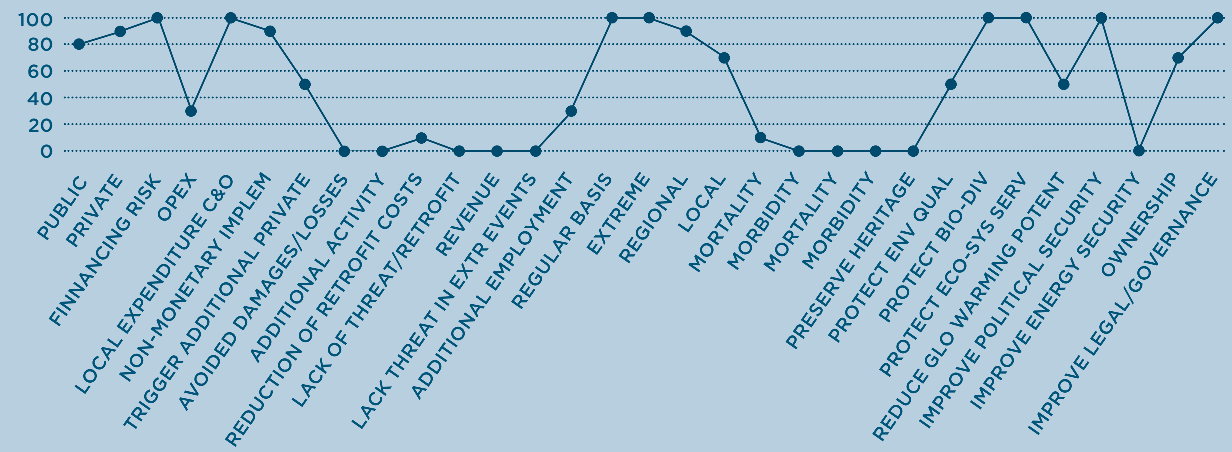


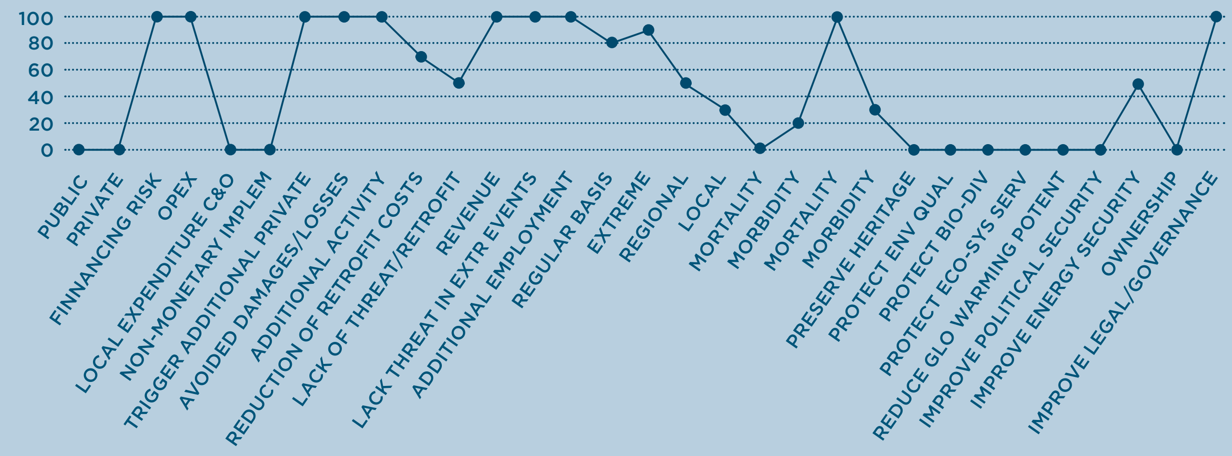
Figure 9: Scoring profile for option Insurance (I)



› The Warnings and Insurance options have similar performance profiles across the input criteria and the economic, environmental and political output criteria, mostly contrasting with that of Retreat. Their performances diverge with respect to the social output criteria.

› The Building Codes option performs in a similar way to Warnings and Insurance on the input criteria; on the output criteria, it performs strongly with regard to the environmental and political criteria.

Figure 10: Scoring profile for option Enforced Retreat (ER)



› The profile of the Public Transport option is distinct from the others, performing generally very well on the input criteria and showing some strengths and weakness within each of the four 2nd-level output criteria.

None of the five options dominates or is dominated by any of the other options at this level of analysis.

The next step was to determine weights for each of the criteria to enable the combination of the scores to reflect the aggregate performance of options at higher levels of the criteria tree. The weighting of sub-criteria within each of the five criteria families/groups (Inputs, Economic, Social, Environmental and Governance), was carried out by the relevant theme expert using the swing-weighting method (described in section 3).

These values were processed using a decision support software — a web-based multi-criteria decision-making tool to enable further analysis (i.e. no option is obviously the best or worst).[11] Higher-level criteria were not assigned weights by the group as they did not have enough information about the likely preferences of the main stakeholders to be able to make this judgement. Instead, extensive sensitivity analyses were carried out to explore the impact of different weightings of the input criteria.

A real benefit of using decision-support software is the ability to play with the assigned criteria weights in order to understand the impact of changing these — small changes reflecting the consequences of imprecision in their specification and large changes potentially reflecting differing stakeholder perspectives, or changing priorities in different

11 V.I.S.A (Visual Interactive Sensitivity Analysis) software – a web-based multi-criteria decision-making tool. More details about the software and how it works can be found www.visadecisions.com.

scenarios. This process enables us to identify any 'tipping points' — points at which the definition of the efficient frontier [12] is changed.

Results and sensitivity analysis

The scores assigned to options for each of the infrastructure theme-specific criteria were aggregated using the criteria weights to determine the overall performance of the options at higher levels of the value tree. The results of the weighted scoring of the five options (shown in Figure 11) revealed the following:

› 2nd level: the pattern of performance against the six 2nd-level criteria is markedly different for each of the options: the Retreat option, again, exhibits the biggest range, performing very well on economic criteria but badly on non-monetary implementation costs. The range of scores is narrowest for Public Transport. But no one option stands out as performing consistently better than any other.

› 1st level: Figure 11 shows the aggregate input and output scores for the options in three different visual displays. Retreat clearly performs less well than the other options; in particular in comparison to Building Codes which has notably higher scores on both outputs and inputs. Retreat is dominated by Building Codes, Public Transport and Insurance at this level of analysis, each of which has higher scores on both inputs and outputs. Public Transport also dominates Warnings, performing better on both input and output criteria. The plot of inputs against outputs (known as an 'efficiency plot' —the chart on the bottom left of Figure 11—) indicates the efficient frontier as a line linking Building Codes, Insurance and Public Transport.

Sensitivity analysis was performed using different weightings for the 2nd-level output criteria. The outcome was that all of the policy options appeared on the efficient frontier in at least one of the cases examined. In the case of the Retreat option, this only happened when the economic criterion was given a bigger weight. The Building codes and Public transport options were robust to changes in weights and were close to or on the efficient frontier in all the cases. The Warnings option, which had an aggregate input score very close to Public Transport stayed close to the efficient frontier, but was just 'dominated' by Public Transport (i.e. the latter had a slightly higher score) except when a bigger weight was given to the environmental criterion. The Insurance option also had an input score close to Warnings and Public Transport; it was dominated by Public Transport when a bigger weight was given to the economic or social criteria, but was otherwise on the efficient frontier.

12 Efficient frontier: the curve generated by the those options that have the highest expected output or return possible for the given level of input.

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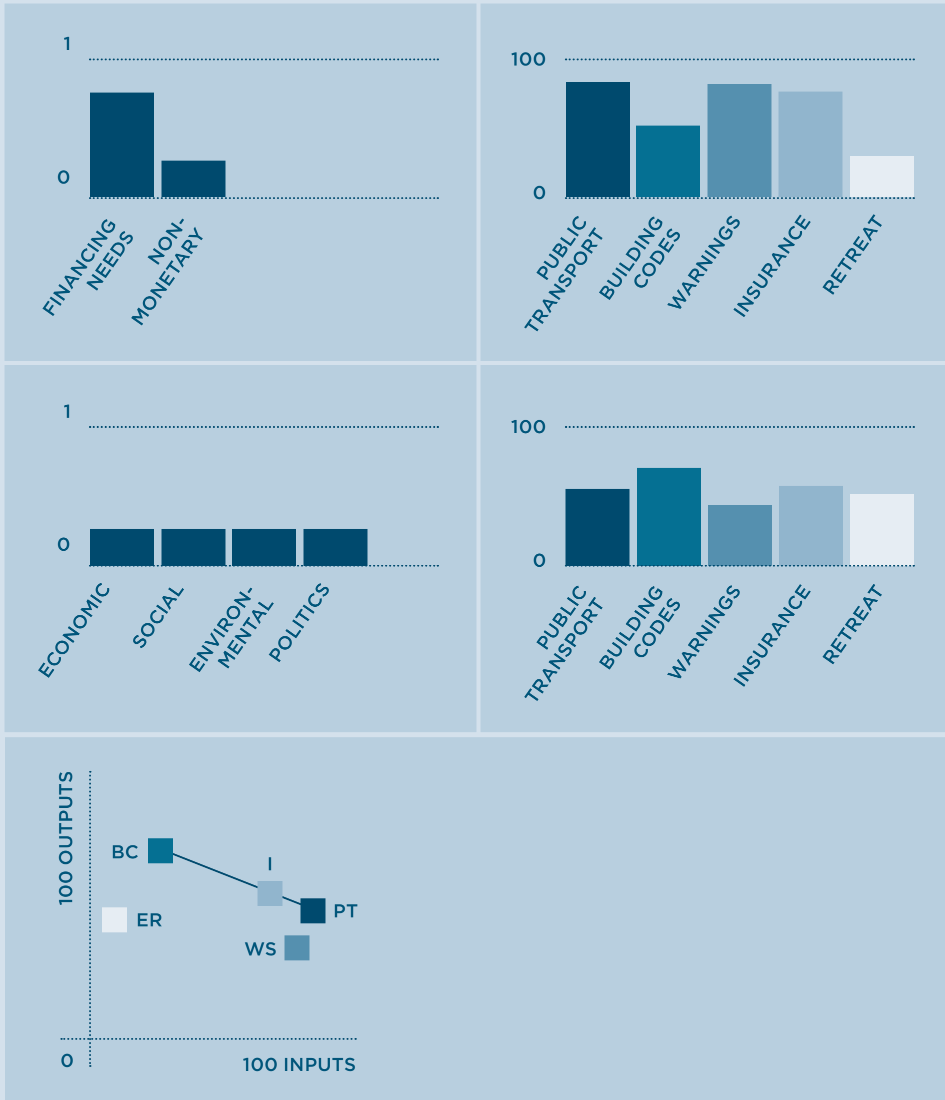
This chart shows the performance of different options for a given set of weights. The top left chart displays the set of weights chosen for the 2nd level input criteria. The middle left chart displays the set of weights chosen for the second level output criteria. The top right and top middle charts show how the options performed across the 2nd level input and output criteria. The input-output chart at the bottom left shows the performance of each of the five infrastructure policy options against aggregated inputs and aggregated outputs. A high input score reflects better performance in terms of minimizing inputs (e.g. less expensive) and is therefore preferred. A high output score is also preferred. This efficiency plot shows that, if the criteria are weighted as shown, Building Codes, Insurance and Public Transport are candidates for the best option. Choice between these would depend on the relative weights assigned to outputs versus inputs.

Figure 11: Performance of policy options for a given set of weights



The impact of changing the relative weights of input criteria, with the same set of output criteria weighting considered above, was also examined. Generally, the positions of Building Codes and Public Transport improved slightly (i.e. they were more efficient relative to the other options as a consequence of their consistently good performance on the financial input criteria). When the emphasis was reversed and a bigger weight was given to non-monetary inputs, the aggregate input scores of Building Codes and Public Transport, which did not perform well on this criterion, were significantly lower.

The main aim of this case study was to test the MCA4climate policy evaluation framework in a situation where policy options are interdependent. A secondary aim was to apply the framework under different climate scenarios and account for climate uncertainty. Yemen was chosen because it has pressing near-term problems with water management that would need to be addressed in conjunction with any planning for adaptation to the effects of climate change. [13]

Given Yemen's heterogeneity, we decided to focus on the impacts and performance of policy options in a single hydrologic basin. In other words, policies might be implemented at a national level, but we would evaluate their likely performance locally. The Sana'a Basin was selected as the target basin because it contains both extensive irrigated agriculture and the rapidly-growing capital city, for which water and sanitation services are inadequate. In addition, the basin is facing rapid depletion of its limited groundwater resources as a result of the explosive growth of groundwater pumping for irrigated agriculture that followed the introduction of diesel pumps in the 1970s and heavily subsidized diesel prices. This has resulted in a short-term agricultural boom period, but alarming drops in aquifer levels and loss of springs that formerly provided critical community water supplies. Only in recent years has the central government reduced fuel subsidies and launched a programme of legal reform intended to constrain further expansion of groundwater use. Climate change could exacerbate an already worsening water crisis in the Sana'a Basin. Any climate adaptation options would, therefore, need to reinforce efforts to address the current crisis. Thus, the set of adaptation options selected for analysis reflects the types of policies that are being implemented, or have been suggested, to deal with the on-going over-exploitation of groundwater resources. The major difference is that we would propose a more rapid and larger effort for each option than is currently planned.

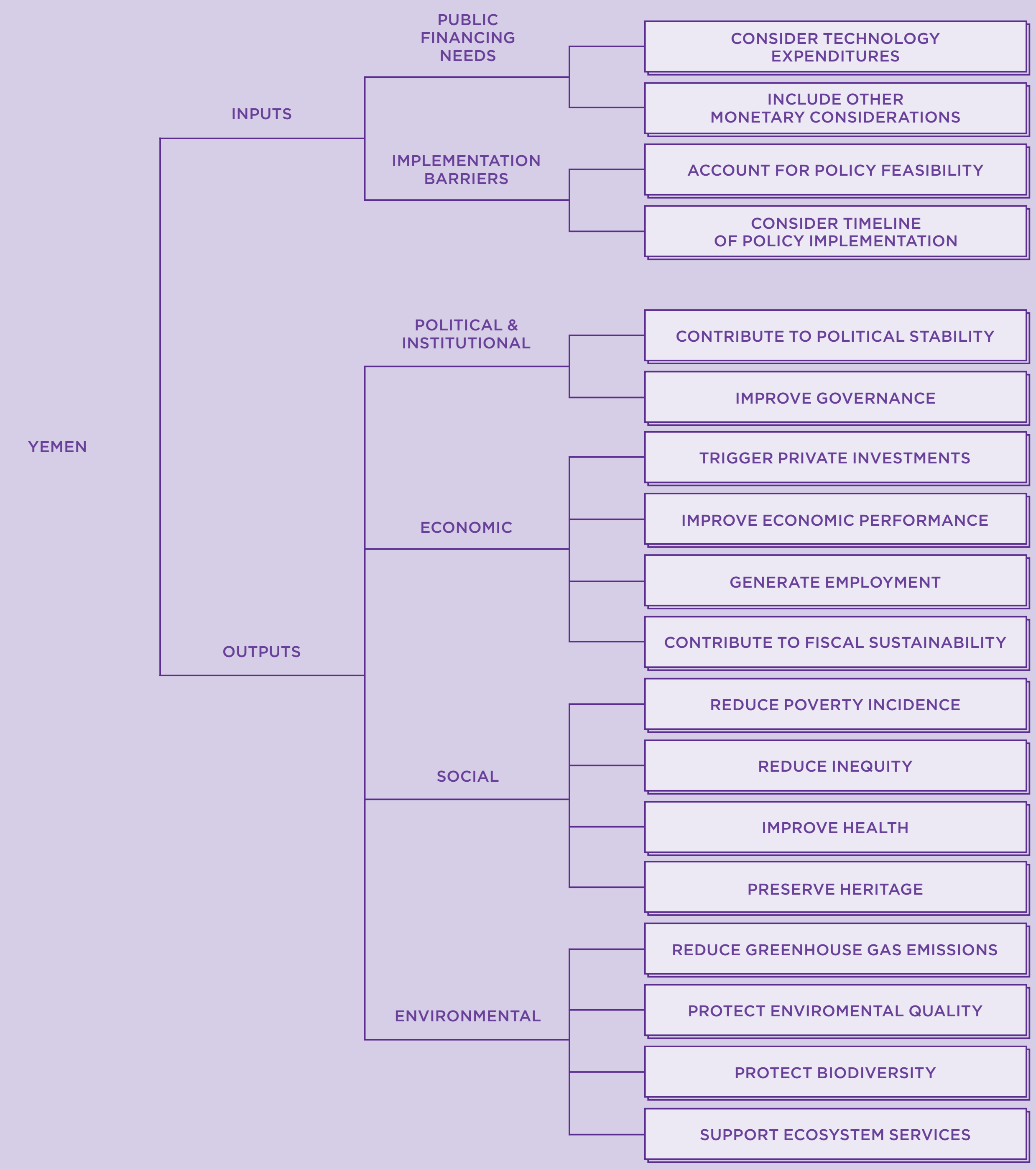
Criteria and policy options

The first step was to adapt the generic criteria tree to evaluate the relative merits of alternative water-sector adaptation options (see Figure 12). The tree was extended to include more detailed water theme-specific criteria. However to facilitate the exercise of evaluating the policies, we decided to concentrate on scoring options at the higher, 3rd-level criteria, using the water theme-specific criteria only to inform our thinking about how we would do this.

We selected a set of eight options for analysis, including three basin-wide options (labelled BW1, BW2 and BW3); three focused on the urban water sector (U1, U2 and U3) and two focused on rural agricultural water use (R1 and R2). Some of these are themselves actually packages of measures that would be implemented together.

13 As indicated, these weights represent only an arbitrary starting point. Weights at higher levels of the criteria tree are determined by the sum of the weights of their sub-criteria, the approach adopted is an 'equitable' assumption. However, criteria containing a larger set of sub-criteria should not necessarily be given more weight than criteria with a smaller set of sub-criteria.

Figure 12: Yemen case study criteria tree



The adaptation options are described in Table 18. It was known at the start of the work on this case study that the adaptation options are not independent of one another. This became clearer as the work progressed. In particular, the presence or absence of governance reforms would have significant impacts on behavioural responses to other policy options, and therefore on their effectiveness. Such governance reforms would first clarify who has the right to use water, the quantitative limits on the use rights, and the locus of decision-making authority to modify use rights. The reforms also would create enforcement mechanisms to ensure compliance with legally-defined rights and obligations. Similarly, monitoring systems are a necessary component of any water management programme. As a result, we assumed that basic physical monitoring systems would be in place (even where they are currently inadequate) and that monitoring of water use, and of activities that could jeopardize water quality would occur as part of a package of governance reforms.

Scoring the options

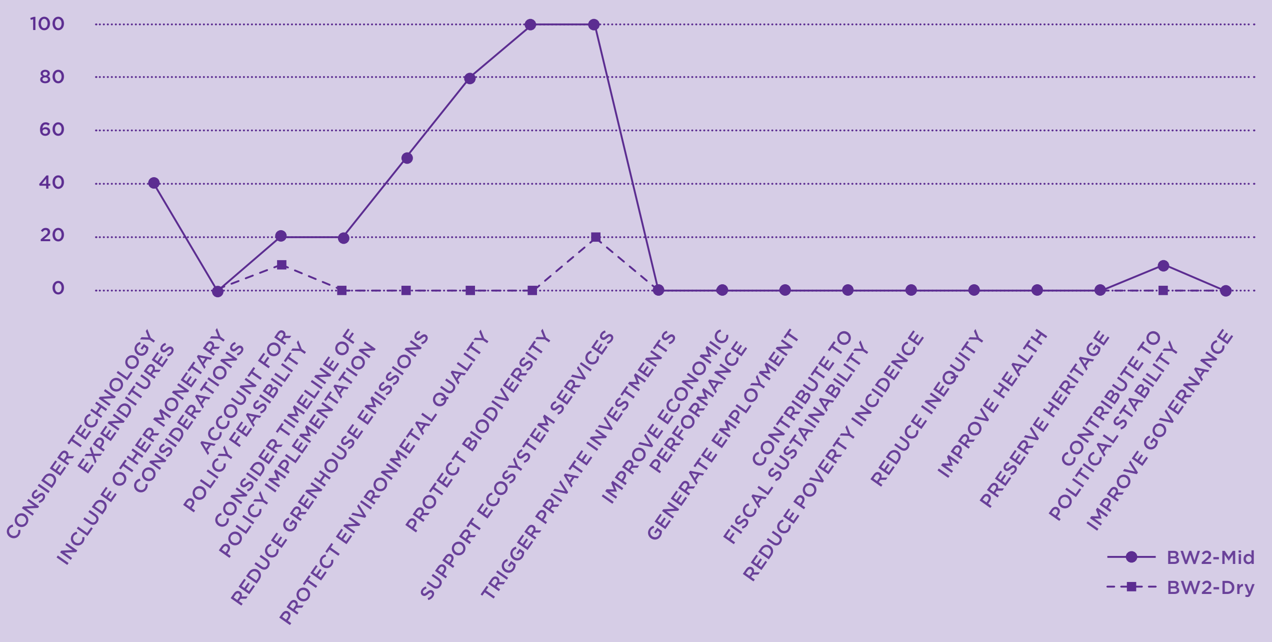
Before the options were scored, it was necessary to decide how to take into account the uncertainty surrounding the impact of climate change on Yemen. Two climate-change scenarios prepared by the World Bank (2010) were selected: a mid-range scenario with moderate warming (an increase of 3.1°C over 1990 levels by the 2080s) and small precipitation changes (decrease 3%), and a hot-dry scenario with amplified warming (increase 4.5°C) and significant declines in precipitation (decrease 24%) resulting in major reductions in runoff and recharge. These differences would have large impacts on water availability and on policy effectiveness over the long term. The initial set of scorings rated the options individually and did not assume that the governance reforms (which make up option BW1) were in place when other options were scored. Because many of the other options would perform poorly in the absence of governance reforms, and because there are likely to be other interactions among the options, climate adaptation policymakers would, in reality, need to compare portfolios of options. Another issue that policymakers would need to consider is the sequencing of policies. Clearly, low-hanging fruit — actions that cost little, but promise significant improvements — should be pursued first. In practice, the issue of interdependence among options affects the appropriate sequencing and packaging of options into portfolios of activities that need to be pursued in tandem in order to be most effective.

In the case study, the individual options were initially scored for each scenario according to how well they would serve each criterion when viewed from the perspective of the end of the period of analysis — the decade of the 2080s. As with the Mumbai case study, a score of 100 was given to the policy that seemed to best serve

Table 18: Policy options to improve water management in Yemen

POLICY	DESCRIPTION
BASIN-WIDE	
BW1: Strengthen basin-wide water p lanning & governance	The most complex and comprehensive of the options considered. Accelerated implementation of the following reforms, which are already underway, was assumed: Establishment of a process for basin-wide determination of limits on total water use by area and type. Requirement for full coverage of irrigated land within water user associations (WUAs). Enhanced powers and responsibilities of WUAs to implement and enforce limits on well-drilling and water extraction. Legal mechanisms for transfers of water extraction rights and land easements
BW2: Retire lands from agricultural use	Creation of a public programme to purchase land currently used for irrigated agriculture and to return it to a natural state. A target of 25 % reduction (c.6 000 ha) in irrigated hectares was assumed. The effectiveness of this option would depend heavily on implementation of other governance measures, because without those reforms, there would be nothing to keep other land-owners from expanding irrigation operations on other lands.
BW3: Integrate land and water management	A set of projects to augment groundwater recharge and limit drawdown by instituting a low-cost loan or matching grant programme to maintain and restore terraces for soil and water conservation, and build spate check dams and recharge basins.
URBAN	
U1: Protect the quality and usability of existing water resources	Reverse the present trend of urban-source pollution of shallow groundwater resources, primarily from untreated sewerage, by improving sewerage and waste-water treatment systems and by providing other waste management services.
U2: Provide desalinized sea-water to Sana'a	Install solar-powered desalination plants on the coast and use solar power to pump the water uphill to the Sana'a Basin. Assumes a 1 billion cubic metre/year plant and pipeline at a capital cost of USD $6 billion with a cost of delivered water of USD 1 per cubic metre.
U3: Implement urban water demand management	Reform public water tariffs for the purpose of collecting sufficient funding for system improvements, including developing a system for metering, billing and revenue collection that would use increasing block rate pricing to keep lifeline water rates low while charging higher rates to households that use large amounts of water. It was assumed that this policy would provide enough revenue to pay for major system improvements that would allow all urban households to have access to safe, reliable public water supplies, although not necessarily in-home taps.
RURAL	
R1 Create incentives to promote efficient use of agricultural water.	Eliminate remaining subsidies on diesel, as well as the agricultural import restrictions that had helped to spur the race to exploit groundwater reserves for irrigated agriculture. It was assumed that the government would continue raising diesel prices to world-market levels, and would eliminate import restrictions/tariffs on fruits, vegetables and qat.
R2: Create incentives to promote demand-side technology uptake.	Extend current programmes aimed at increasing crop output and income per unit of irrigation water consumed (e.g. provide low-cost loans to install piped irrigation systems, mulching and similar investments to conserve water). It was assumed that the government would make these programmes available to any willing farmer in the Sana'a Basin. It was also assumed that the policy would be implemented without any restrictions on eligibility or on the total extent of irrigated land in the basin.

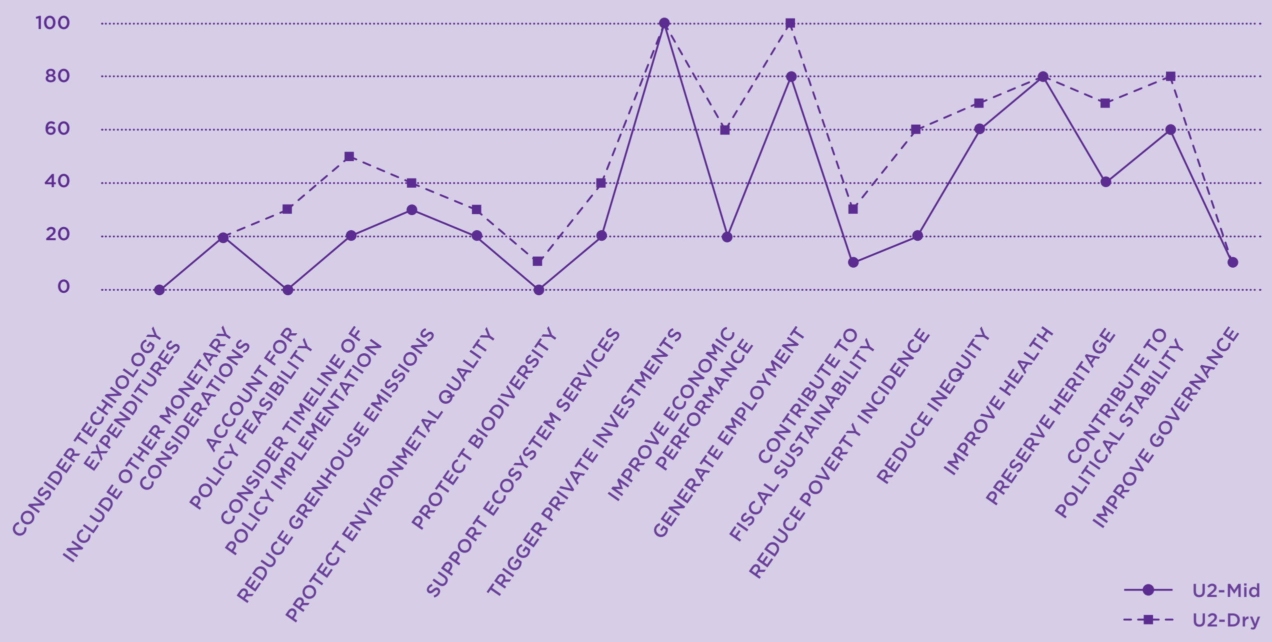
Figure 13: Scoring profile for option BW2 under different climate scenarios



the criterion and a zero to the one that would be least effective (or even damaging). There are some striking differences in the scorings between the two scenarios, for example:

- BW2 and R2 perform better in the mid-range scenario. In the case of BW2 (retiring agricultural lands) there is a dramatic reduction in the expected environmental benefits in the hot-dry scenario compared to the mid-range scenario, as seen in Figure 13. This reflects the assessment that if the governance reforms are not strengthened significantly beyond those already underway, there will be very little water available by the 2080s and little groundwater-based irrigation left to manage in the hot-dry scenario. In the mid-range scenario, it was assumed that the reforms currently underway would be successful in extending the life of the aquifer and that steady-state groundwater abstractions could be maintained at a rate equivalent to average annual recharge.
- U2 (desalinized water for Sana'a), BW1 (strengthen basin-wide planning and governance) and R1 (promote efficient use of agricultural water) all perform better in the hot-dry scenario relative to mid-range scenarios, as seen in Figures 14, 15 (See next page) and 16 (See next page).

Figure 14: Scoring profile for option U2 under different climate scenarios



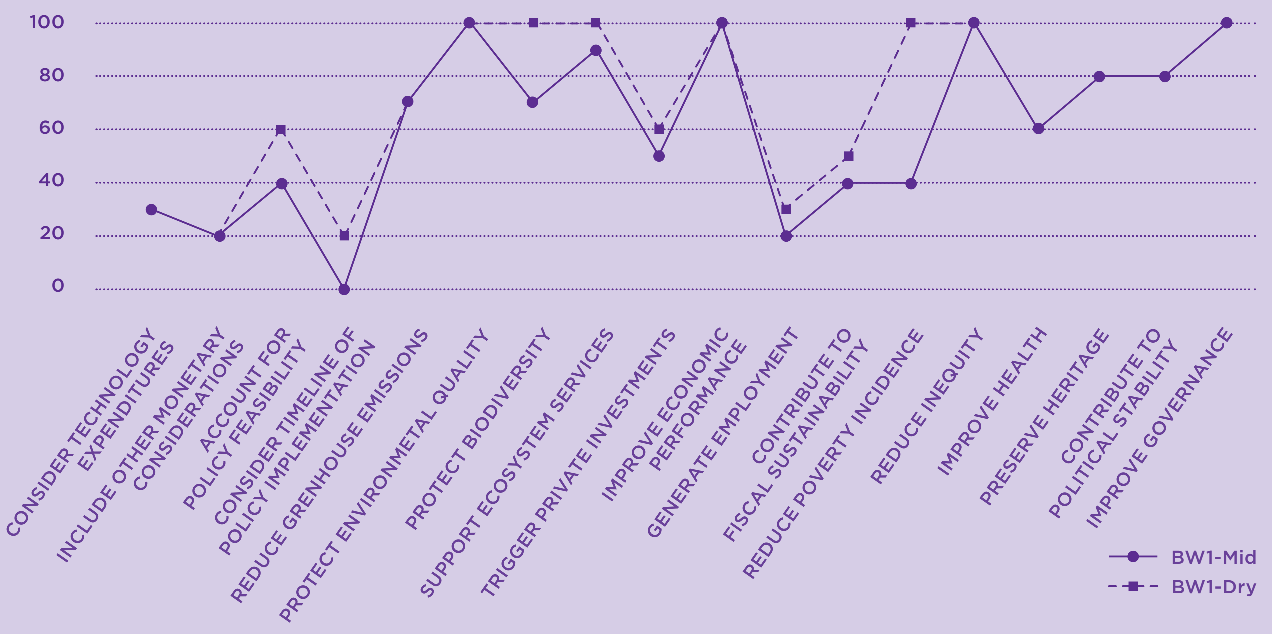
Results and sensitivity analysis

The weighting of criteria at the 3rd level of the tree used the swing-weighting process described earlier (in section 3). As the analysis is illustrative and the group did not know what the priorities of real decision-makers would be, a rough five-point scale was used to capture these initial judgements.

As a starting point, the weighting of criteria at the 2nd level of the criteria tree put greater emphasis on implementation barriers within inputs and weighted the four output families proportionally to the number of 3rd-level criteria (so the political-institutional family weight is half that of each of the economic, environmental and social families). The weights were combined with the scores for the 3rd-level criteria to yield aggregate results at the higher levels of the criteria tree. The results comparing the aggregate input and output scores are shown for the mid-range scenario in Figure 17 (See page 86) and for the hot-dry scenario in Figure 18 (See page 87).

The options performed quite differently on the input and output criteria: generally, R1 (incentives to promote efficient use of agricultural water), and R2 (incentives to promote demand-side technology uptake) performed well on inputs in both scenarios, while BW1 (strengthening of basin-wide water planning and governance)

Figure 15: Scoring profile for option BW1 under different climate scenarios



performed best on outputs. There were also differences in performance between the mid-range and hot-dry scenarios. For example, looking at BW2 it can be seen clearly from the bar charts (in Figures 17 and 18) that its score on both inputs and outputs is higher in the mid-range scenario. The efficient frontier is defined by BW1 and R2 in the mid-range scenario and by BW1 and R1 in the hot-dry scenario. The position of the other options relative to the frontier is unchanged between the two scenarios; BW2, U1 and U2 are dominated by BW1 in both scenarios and BW3 and U3 are dominated by R2 in the mid-range scenario and R1 in the hot-dry scenario. Sensitivity analysis was then carried out by varying the weights on each family of criteria. In the mid-range scenario increasing the weight on environmental factors moved option R1 closer to the efficient frontier, while increasing the weight on social factors moved option U3 (urban water demand management) onto the frontier midway between R2 and BW1. Increasing the weight on the other two output criteria families did not change the composition of the efficient frontier. In the hot-dry scenario U3 once again moves onto the frontier when increased weight is given to social factors.

The analysis so far had focused on the evaluation of individual options. However, as mentioned above, there are clear synergies rising from the combination of certain options (see also Box 2). To explore this, we created portfolios by combining the original eight options into portfolios

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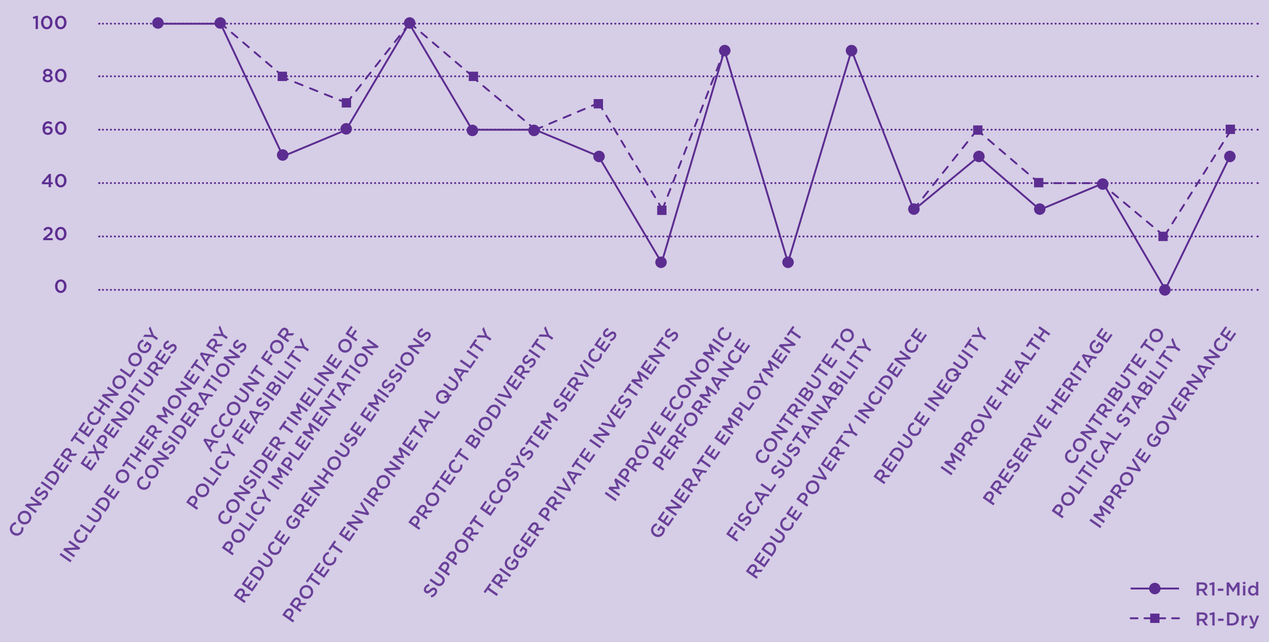
Figure 16: Scoring profile for option R1 under different climate scenarios



of two or more options. This created 255 permutations. As a first step we made the simplifying assumption that the total associated inputs required and outputs generated are simply the sum of the inputs and outputs of the individual projects. The performance of each of the portfolios is shown in Figure 19 (See page 88), plotting the total outputs against the total inputs.

Box 2: Approaches to evaluating portfolios of policy options

The evaluation of portfolios can be approached in different ways. One way is to pre-define portfolios of options for which there would be significant interaction effects and to score each of these portfolios alongside the individual options. This ensures a robust evaluation of the portfolio options, but if there are many of these it substantially increases the work involved in scoring them.

Another approach is to make a broad assumption about the nature of the interaction effects and to mathematically generate scores for all possible portfolios based on this. This approach, which we adopted for this case study, greatly eases the evaluation burden, but the value of the analysis depends on the realism of the assumptions made.

The portfolios which are of greatest interest are again those which lie on the efficient frontier, which, in this case is towards the top left-hand corner of the plot. The frontier is defined by the portfolios which generate the greatest outputs for a given level of input. It defines what is sometimes referred to as 'the order of buy'. If limited resources were available, the first option that we should invest in is R2 (a portfolio of one option), which generates the greatest output for the lowest level of input. If more resources (input) are available,

The top left and top middle charts display the set of weights chosen for the 2nd level input and output criteria. The top right and top middle charts show the aggregate scores for inputs and for outputs across the eight water management adaptation policy options considered in the Yemen case study. The input-output chart at the bottom shows the performance of each of the eight water policy options against aggregated inputs and aggregated outputs: this efficiency plot suggests that BW1 (strengthen basin-wide water planning and governance) and R2 (promoting demand-side technology uptake) are the best options for this allocation of weights. Choice between these would depend on the relative weights assigned to outputs versus inputs.

Figure 17: Performance of policy options in the mid-range scenario

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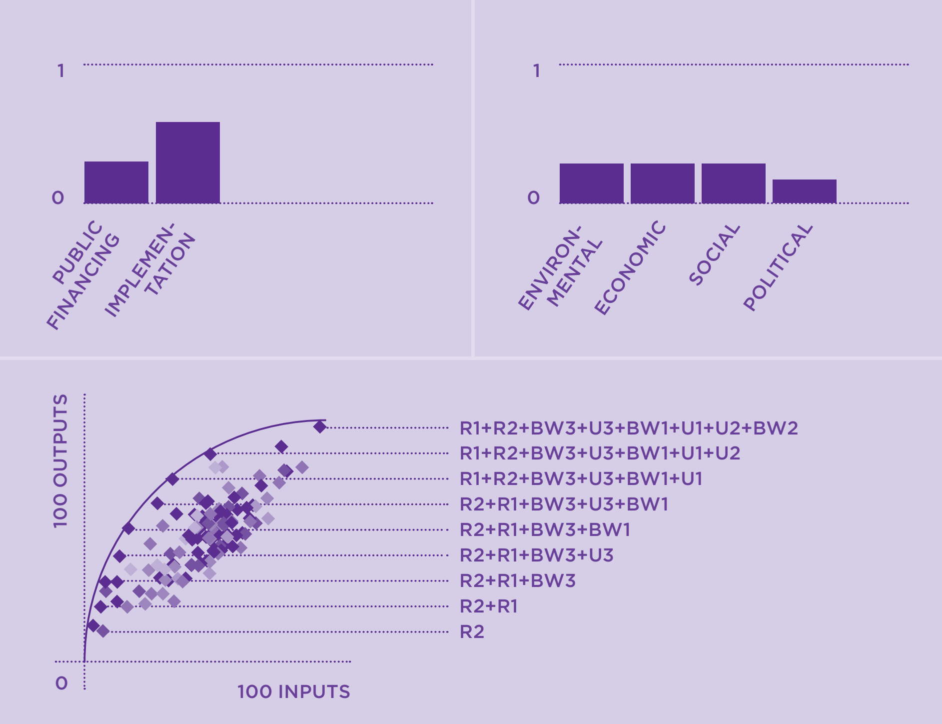
then the best use of these is achieved by stepping up the efficient frontier adding options to the portfolio as indicated by the labels in Figure 19. The next option to add to the portfolio is R1 (giving the portfolio R2+R1), followed by BW3, and so on. All the portfolios which lie below the efficient frontier are inefficient — this means that greater output could be achieved for the same input, or the same output for less input. The last option to be added to the portfolio moving up the efficient frontier is BW2, which, as the initial scoring showed,

The top left and top middle charts display the set of weights chosen for the 2nd level input and output criteria. The top right and top middle charts show the aggregate scores for inputs and for outputs across the eight water management adaptation policy options considered in the Yemen case study. The input-output chart at the bottom shows the performance of each of the eight water policy options against aggregated inputs and aggregated outputs: this efficiency plot suggests that in the hot-dry scenario BW1 (strengthen basin-wide water planning and governance) and R1 (promoting efficient use of agricultural water) are the best options for this allocation of weights. Choice between these would depend on the relative weights assigned to outputs versus inputs.

Figure 18: Performance of policy options in the hot and dry scenario

The results are based on the scores for the mid-range scenario and the weighting of criteria at the 2nd level is shown. The input scores had to be inverted to allow for the portfolio analysis: a high input score in the portfolio analysis corresponds to a high input requirement, i.e. less preferred (more expensive).

Figure 19: Performance of all portfolios of policy options

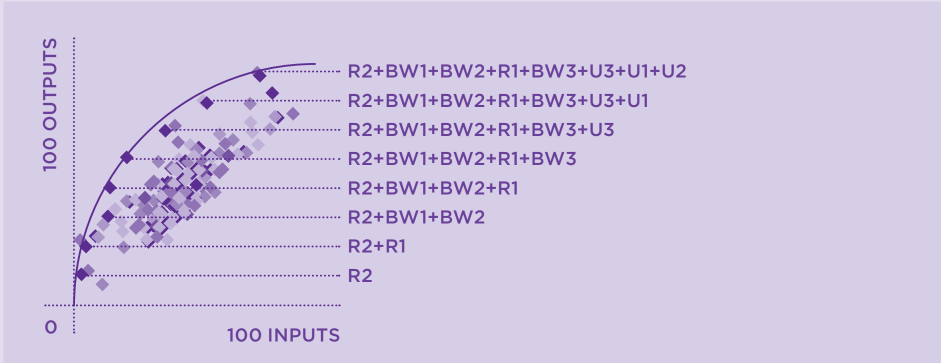


generates low outputs in relation to the inputs required. However, the performance of this option would be substantially improved if it was implemented in conjunction with improved governance measures such as those incorporated in option BW1. Further analysis, which took account of this synergistic effect by doubling the scores where both BW1 and BW2 are included in the portfolio, resulted in a significant shift in the efficiency frontier (Figure 20).

The results are based on the scores for the mid-range scenario

Figure 20a: Original plot highlighting all portfolios which incorporate options BW1 and BW2

Figure 20b: Revised plot taking account of synergy between options BW1 and BW2



Opposite:
The rightmost column represents an additional scenario analysed in this case study using the MCA4climate criteria tree; Zeros correspond to missing information on the indicator measuring the associated criteria

This case study focused on the application of the MCA4climate policy evaluation framework to a policy and planning process which was undertaken in South Africa in 2010 to determine a more appropriate fuel (and technology) mix for electricity generation over the next 20 years — namely the Integrated Resource Plan 2010 (IRP-2010). The case study was based on the energy-modelling outputs for five scenarios in the IRP-2010 process and one additional scenario from a parallel energy modelling process that was conducted for the Revision of the White Paper on Renewable Energy Policy (REWP). The aim was to compare and contrast the results of applying the MCA4climate framework with the multi-criteria decision making framework (MCDF) that was used to prepare IRP-2010, so as to demonstrate the impact of incorporating broader developmental concerns (as well as an additional renewable energy scenario) into the analytical framework and decision-making process.

Although this case study considered energy scenarios reflecting different technology/fuel-mix investment options rather than policy scenarios, they can nonetheless be seen as representing the outcomes of climate policies (without specifying the types of energy-policy instruments or measures). Using these scenarios (already modelled in the IRP study) enabled us to make use of more data in the form of quantitative indicators than in the two other case studies. Clearly, an appropriate combination of policies would still need to be identified (or developed) to shape the investment decisions which would result in the optimal energy scenario.

Background

South Africa's electricity generation — and the energy system generally — is heavily reliant on fossil fuels and is consequently highly carbon-intensive. Approximately 85% of the net capacity in the country is based on coal-fired thermal generation. The power sector is dominated by the national electricity utility, Eskom. It generated 232 TWh in 2010, equal to more than 95% of total generation in South Africa. Eskom has installed capacity of 44 GW, comprising 13 coal-fired power stations (38 GW), one nuclear plant (2 GW), four hydro and pumped-storage schemes (2 GW) and four gas-turbine stations (2 GW). The balance of the generation capacity in the country is provided by a handful of municipal and private generators. In addition, the country imports electricity, mainly from the 2 GW Cahora Bassa hydropower plant in Mozambique. South Africa has suffered from persistent power shortages in recent years, leading to blackouts and brownouts (a drop in voltage), mainly as a result of rapid growth in demand. Nationally, the reserve margin — the difference between available capacity and peak load — fell to under 6% in March 2008, though it has since increased to around 15% through operational improvements, including improved

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Table 19: Mapping IRP 2010 criteria against MCA4climate 3rd level criteria

LEVEL 3 CRITERIA	DRAFT IRP 2010 CRITERION	SCENARIO	1	2	3	4	5	6
		UNITS	BASE CASE	EMISSION LIMIT	REGIONAL DEVELOPMENT	ENHANCED DSM	REVISED BALANCED SCENARIO	RENEWABLE ENERGY
Minimize spending on technology	Present value of total cost	ZAR millions	789481	1257457	832388	826429	848906	1540000
Minimize other types of spending			0	0	0	0	0	0
Allow for easy implementation	Portfolio risk or uncertainty		687	521	699	686	611	699
Comply with required timing of policy intervention			0	0	0	0	0	0
Protect environmental resources			0	0	0	0	0	0
Protect biodiversity			0	0	0	0	0	0
Support ecosystem services	Average annual water consumption	ML/annum	327	283	326	324	318	338
Trigger private investments	%	%	5	10	5	35	85	100
Improve economic performance	Peak price of electricity	c/kWh	100	172	101	104	111	115
Generate employment			0	35	25	55	75	100
Contribute to fiscal sustainability		%	35	85	35	55	55	95
Reduce poverty incidence			14	6	0	37	26	100
Reduce inequity			50	50	35	55	85	100
Improve health			0	75	45	65	85	100
Preserve cultural heritage			0	0	0	0	0	0
Contribute to political stability	Regional development		687	385	1040	687	863	0
Improve governance			50	55	45	65	55	100
Reduce greenhouse gas emissions	Average annual CO2 emissions	Mt/annum	303	236	301	299	271	249
Enhance resilience to climate change			0	65	55	80	75	100

coal-supply management. The prospect of continuing increases in electricity demand — driven in part by expanded electricity access for poor households — and the need to replace some existing capacity that will have to be retired mean that a significant amount of new capacity will have to be added in the coming years, unless demand growth can be curbed. New generating assets may include less carbon-intensive technologies. A central energy-policy challenge, therefore, is to reconcile energy poverty- and climate-policy goals.

Scenarios and criteria

The six scenarios that were assessed are set out in Table 20. Notably, only the sixth scenario, the REWP scenario, would meet the climate commitments of the South African government. All of the scenarios were based on a 20-year planning horizon, extending to 2030.

Scoring and weighting the scenarios

For this case study, the data underlying the IRP-2010 multi-criteria analysis was used to inform the scoring of the scenarios against the more development focused and comprehensive MCA4climate criteria. IRP-2010 used five criteria: cost, climate change mitigation, portfolio risk or uncertainty, localization benefits and regional development benefits. For some of the MCA4climate criteria, quantified data for specific indicators were available from the energy modelling carried out as part of the IRP process; where data were not to hand, more subjective judgements were used by the workshop participants to score the performance of different scenarios against the MCA4climate criteria.

Table 19 (See previous page) shows the mapping of the six indicators used in the draft IRP-2010 on to the MCA4climate criteria tree and the associated scoring. For the criteria for which data were available from the energy modelling the quantitative scores were transformed to a 0 to 100 scale, where 100 represents the preferred performance. Subjective judgement by experts was required to score and rank the unquantified criteria. Where possible, this was done using the same process of direct rating of the options against a 0 to 100 'locally defined' scale as described in the previous case studies. It was not possible to score five of the level-3 criteria due to lack of information (all scores for these criteria are shown as 0 in Table 19).

Figure 21 (See next page), which shows a graphical comparison of three of the six options highlights the strength of the Renewable Energy option across the output criteria. However, this is achieved at the expense of a zero score on the two input criteria (reflecting the highest level of inputs of all 6 options). Comparing the other two options shown in Figure 23, Enhance DSM and Regional

Table 20: Integrated resource plan scenarios in South Africa

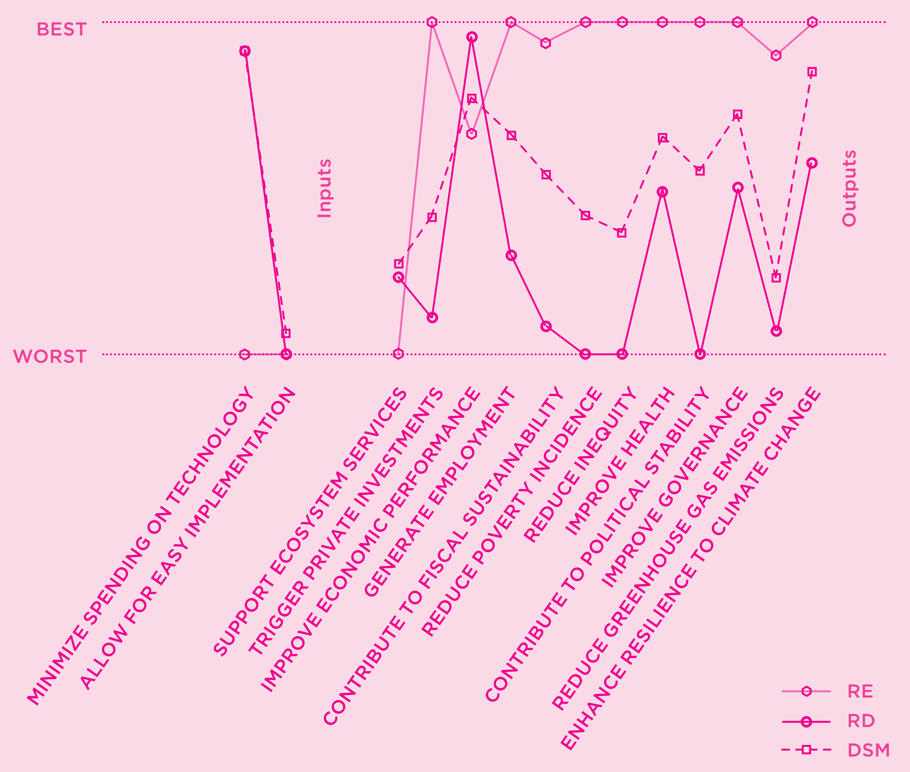
SCENARIO	DESCRIPTION
BC: Base Case	This provides for limited regional development options and makes no allowances for externalities (such as a carbon tax) or climate-change targets. Key features: — Committed build and decommissioning — Some imported hydro — Combined-cycle gas-turbine (CCGT) plants — Imported coal — Fluidised bed combustion coal technology — Pulverised fuel (PF) + flue gas desulphurisation (FGD) — Open-cycle gas turbine (OCGT) plants for peaking
EL: Emission Limit	This scenario adopted the imposition of an annual limit for CO_2 emissions from the electricity sector of 220 Mt CO_2-eq from 2020. Key features: — Committed build and decommissioning — Wind capacity (17.6 GW starting in 2015) — Solar capacity (11.25 GW commissioned between 2017 and 2021) — 9.6 GW of nuclear capacity — CCGT — OCGT for peaking (6.5 GW)
R: Regional	This scenario included additional regional projects as options, such as: — Increased hydro imports — Increased coal-fired imports — Includes transmission upgrades
DSM: Enhanced DSM	This scenario included a more aggressive demand-side management programme with an additional 6 TWh per year of electricity demand reduction imposed by 2015.
RB: Revised Balanced	This scenario represents a trade-off between least-cost investment, climate change mitigation, diversity of supply, localisation and regional development. It includes solar, wind, cogeneration, nuclear power and imported electricity.
RE: Renewable Energy	This scenario is based on energy modelling in the revision of the RE White Paper of various renewable energy options in addition to grid-connected electricity generation, including: — 9.2 million solar water heating systems — 330,000 solar home (PV) systems — 60,000 household biogas digesters

Development, it can be seen that the former almost dominates the latter; whilst both have very similar inputs, Enhance DSM outperforms Regional Development on all but one of the outputs (improve economic performance).

Criteria weights were then defined and the scoring was carried out in the same way as for the other two case studies (see above). As with the previous case studies, the group did not have access to real decision-makers thus this part of the analysis is only illustrative. Public financing needs were given a bigger weighting than implementation barriers on the input side; the policy criteria were weighted more heavily than the other four groups of criteria on the output side. The results aggregated to the level of Inputs and Outputs can be seen in Figure 22.

Three options, the Renewable Energy scenario, Emissions Limit scenario and Revised Balanced scenario lie on the efficient frontier given this initial specification of weights. Which of these is preferred overall will depend on the relative weights assigned to Inputs and Outputs; if the weight on outputs exceeds 0.8 then the Renewable Energy scenario performs best overall, if it is less than 0.6 the Revised Balanced scenario performs best and between 0.6 and 0.8 the Emissions Limit scenario is preferred. IRP-2010, which allocated weights across the six criteria considered, found that the Revised Balanced scenario was optimal. The Base Case scenario exhibits the lowest output / input relationship (ratio) in our analysis; together with Regional Development and Enhanced DSM it is dominated at this level by the Revised Balanced scenario. Sensitivity analysis was then carried out to test the results by varying the weighting of sub-criteria of inputs

Figure 21: Comparative scoring of three energy planning scenarios



and outputs. Figure 23 (See next page) shows the consequences of increasing the weight on Social outputs, which are particularly important in the case of South Africa when poverty issues such as access to energy services are taken into consideration. The Emissions Limit scenario has moved away from the efficient frontier, which is now defined by just the Renewable Energy and Revised Balanced scenarios. The position of the other three options (Enhanced DSM, Regional Development and Base Case) is unchanged; they are still dominated by the Revised Balanced scenario and remain so for all

The top and middle left charts represent the weights given to the input, and respectively, the output criteria. The top and middle charts show the scoring of the six energy planning scenarios when aggregating across inputs, and respectively outputs. The bottom left chart shows the performance of the different energy scenarios at the highest level (inputs versus outputs) for the weights given.

Figure 22: Performance of different energy planning scenarios

This figure shows the performance of the different energy scenarios, when the weighting on social output criteria is increased. The results are shown at the highest level (inputs versus outputs).

Figure 23: Performance of energy planning scenarios when more weight is given to social outputs

combinations of weights considered. The Revised Balanced scenario remains efficient whichever input criterion is weighted highly.

When economic or social factors are weighted more highly, the Renewable Energy scenario also remains on the efficient frontier but the Emission Limit scenario moves away from it. If environmental factors are emphasized then the situation is reversed and the frontier is defined by the Emission Limit and Revised Balanced scenarios, with the Renewable Energy scenario moving off it.

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Lessons learned

Although the three case studies are intended only to be illustrative, each highlights a different aspect of good practice in the specification of options for evaluation: in the Mumbai case study, the options for evaluation were deliberately chosen to reflect the wide range of possibilities to solve the problem; the Yemen case study demonstrated the importance of looking not only at individual activities but also at the potential synergies between them; and the South African case study illustrated the process of iterative development. The latter involved the ability to build upon existing work (e.g. the initial IRP-2010 study for South Africa) and improve policy planning processes by applying the MCA4climate initiative and widening the criteria to cover important developmental impacts such as poverty and energy access.

The three case studies attempt to demonstrate the value of the MCA4climate policy evaluation framework as a practical aid to policy-making, as well as the usefulness of the theme-specific operational guidance and the guiding principles of climate-policy analysis. The results also helped to refine the framework, particularly the design of the criteria tree, and provided important insights into the way it can best be applied in a real world situation. Among the specific lessons learned were the following:

- There can be important interactions among different types of mitigation and adaptation options that have important implications for how well the individual options will work in practice. Consequently, policy assessments should consider alternative portfolios of options as well as efficient sequencing of options within a portfolio.
- The weighting of different criteria can have a profound effect on the relative value of different policy options.
- It is preferable to identify and agree on criteria and carry out initial scoring of policy options before undertaking detailed energy and economic modelling in a climate-policy planning process to ensure that the outputs of the modelling are useful in applying the MCA4climate framework or any other multi-criteria analysis tool.
- The framework provides a powerful means of enabling a wide range of stakeholders to engage in the complex climate-policy decision-making process to ensure that appropriate weights are given to different criteria, including those concerned with social and economic development.

Evaluating the various climate-policy options in order to come up with a coherent and sound plan is confronted by a number of practical issues, including how to assess the economic implications of the various policy options, how to deal with risk and uncertainty, how to develop and use baselines, how to evaluate the fiscal implications of climate policies and how to go about measuring, reporting and verifying policy actions and their effects. The MCA4climate initiative has developed some guiding principles and practical recommendations on how to address these issues, which are summarized in this section. This guidance is intended to be of practical value to government officials directly involved in formulating climate policies, as well as to other stakeholders involved in the climate-policy making process.

5 Guiding principles for climate-policy planning

Economic analysis of climate-policy options

Evaluating the future socio-economic impacts, benefits and costs of climate mitigation and adaptation policies typically involves the use of detailed empirical research and modelling. That inevitably involves a number of choices about the methodological approach and underlying assumptions, which have important consequences for the projections and, therefore, the ultimate selection of policies to be implemented. Chief among these choices are the following:

- Macroeconomic assumptions.
- Technological innovation, learning, dynamics and feedbacks.
- No-regrets options for mitigation and adaptation.
- Monetary valuation and non-marketed impacts.
- Discounting future costs and impacts.
- Time horizon of the analysis.

Traditional approaches to these issues are arguably ill-suited to analyzing climate policies because monetizing human preferences, ecological properties and technological possibilities is difficult and because the associated techniques neglect important ethical questions. A new thinking on the economics of climate change is emerging which seeks to take these shortcomings into consideration. That thinking is based on the following principles:

- Climate-policy analysis needs to consider, in addition to economic aspects, health, equity, environmental, institutional and ethical perspectives, as well as the interactions between them.
- Due consideration needs to be given to the evolution over time of changes in technologies, which may occur as a response to climate policy and which are themselves influenced by institutional factors and past experiences.
- By avoiding the exclusive use of monetary valuations, important inter- and intra-generational equity and other social and environmental concerns can be included in the analysis.
- Uncertainty and risk, which are central to the assessment of climate-change impacts, should play a major role in the formulation of policy (this issue is discussed in detail below).

Macroeconomic assumptions

Most greenhouse-gas emissions are the direct result of economic activity. Thus the anticipated growth of population and per-capita production and consumption are major drivers of future emissions (see Developing baseline projections, below). The faster the growth in populations and the economy, the faster emissions will tend

to grow. So assumptions about these factors are central to projected emissions growth, which will affect the costs and impact of climate-policy action.

For example, faster assumed rates of economic growth typically imply higher costs for switching to low-carbon technologies, as well as greater potential benefits — i.e. avoided costs — from emissions reduction. The prices of fossil energy and competing technologies are another important driver, as they affect incentives to conserve and use energy more efficiently and the relative attractiveness of investing in low-carbon sources of energy, as well as social welfare. There is no single, standard source of projections on these and other macroeconomic drivers, either at the national or international level. There are three main practical options for dealing with this issue:

- Option 1: Use a very detailed model of climate economics, making as many variables as possible endogenous. This is theoretically appealing, but expensive and difficult in practice.
- Option 2: Select a range of available studies that provide the needed projections of macroeconomic factors (ensuring as much consistency as possible) and calculate the corresponding averages.
- Option 3: Select projections to ensure consistency with other planning studies in the same country.

For assumptions at the international level, it is recommended to apply option 2 to existing sets of projections for exogenous global variables, such as GDP, population, population health and oil prices, unless a global endogenous model sufficiently disaggregated is available (for which option 1 would apply). For macro-level assumptions at the national level, the recommendation would be option 3. If nationally sourced projections are not available or are limited to the short term, other external studies (option 2 may be applied if there are several) or other countries' projections could be used as proxies.

These recommendations apply to the analysis of both mitigation and adaptation policies, though macro-level assumptions play somewhat different roles in each case. Mitigation typically involves decisions about emissions, which are directly tied to production and consumption, so the link between policy and macro-level assumptions is immediate and inescapable. Adaptation actions involve diverting economic resources, and are frequently designed, in part, to protect economic activity.

For both adaptation and mitigation, sensitivity analysis should be carried out to determine the extent to which the assessment of climate-policy options using the MCA4climate policy evaluation framework (as described in section 3) is affected by the macro-level assumptions.

Technological innovation, learning, dynamics and feedbacks

In long-run climate scenarios, assumptions about the flexibility of technology and the pace of technological change are crucial to the projections. Of critical importance are assumptions about whether technology improves automatically (such as in the 'autonomous energy efficiency improvement' assumed in some models), or whether such improvements are driven endogenously by public policy, investments in research and development, and past experience (as in 'learning curve' or 'learning by doing' analyses). Endogenous technology models generally project lower costs of climate policies, as they are assumed to stimulate a virtuous circle of cost-reducing innovation and emissions reductions.

There is a trade-off between aggregate or top-down approaches to technology, spanning society as a whole (or major branches of the economy), and bottom-up approaches that incorporate a more detailed representation of specific technology options in individual sectors. Closely related to this is the question of modelling economic, health, political and environmental dynamics in general, through tools such as systems dynamics modelling. Dynamic models with multiple feedback loops, which rely on extensive time series and cross-sectional datasets, are undoubtedly more realistic, but are also more complex, more difficult to estimate and more sensitive to small fluctuations in technology assumptions. Learning and dynamics also play an important role in adaptation analyses, as they affect vulnerability and adaptive capacity. The main options for dealing with technological change are to:

› Option 1: Assume a fixed pace of technical change, on the grounds of simplicity and ease of calculation of results, even though it does not capture the potential for crucial changes over time.
› Option 2: Assume a limited form of endogenous technological change, and a small number of crucial feedback and dynamic effects of policy choices. This incorporates some of the recent advances in modelling of system dynamics, while stopping short of the full complexity of real-world social processes.
› Option 3: Attempt a full-scale dynamic model with numerous causal pathways and feedbacks, as in some systems-dynamics approaches.

Our general recommendation is option 2, as this approach involves the appropriate level of complexity for most studies. Where resources for policy analysis are limited, option 1 may be more appropriate, though the likely costs and impacts of climate policies may be badly miscalculated. Similar considerations again apply to both mitigation and adaptation, though for slightly different reasons. In analyzing mitigation policies, there is naturally a trade-off between model complexity and the ease of evaluating climate policies. This requires using a particular model of endogenous technical change and relying on econometric techniques where data are available. For adaptation, the emphasis is less on long-term technological change and more on shorter-term feedbacks and dynamics; the process of learning about hazards and how best to adapt to them is crucial to reducing vulnerability.

No-regrets options for mitigation and adaptation

Many bottom-up analyses, such as the McKinsey cost curves, have identified substantial opportunities for mitigation at zero or negative net cost. Similar opportunities for adaptation may also exist. Policies to exploit these opportunities are known as 'no-regrets' or 'win-win'. Such opportunities may not be exploited in practice because of market barriers, such as a lack of information about them or because some of the benefits of the investment that reduces emissions do not accrue to the investor. Co-benefits include, for example, improved health from reducing fossil fuel combustion through less air pollution, and the increased resilience and reduced vulnerability to non-climate shocks that can result from successful adaptation measures. Both mitigation and adaptation policies may bring also benefits of economic diversification and increased employment in new industries or protective investments. In practice, it can be hard to measure co-benefits. How they are taken into account in evaluating climate-policy options can have a large effect on their estimated net costs. There are two main options for how best to handle no-regrets policies:

› Option 1: Use the best available, disaggregated information on no-regrets options. These options will normally be the first priorities in any climate policy proposal, as they reduce the overall costs of a comprehensive climate-policy.
› Option 2: Reject the possibility of no-regrets options, and accept the theoretical economic argument that there must be large hidden costs such that all policy options have positive net costs.

For both adaptation and mitigation, option 1 is the best approach, as it makes better use of the available information about real-world costs. It is important to examine any potential no-regrets options carefully and assess the transactions or programme costs needed to realize the projected savings. Those costs may reduce, but not necessarily eliminate, the projected savings. In general, co-benefits should be included, whenever data are available, in full life-cycle analyses of climate impacts and policy costs; the inclusion of co-benefits can substantially affect the results.

Monetary valuation and non-market impacts

The practice of assigning monetary values to the environmental, health and other social costs and benefits of policy actions has become more common, but remains controversial because of several ethical and analytical dilemmas. These include whether it is necessary to monetize every significant benefit, the availability and use of standard values for non-market benefits and whether to base values on willingness to pay or income (economic logic suggests that they must vary, but are public health and the environment worth more in a rich country?). It is also questionable whether the most important costs or benefits can be reported in natural (physical or health) units as well as in monetary equivalents. For health, for example, values can be calculated for individual outcome categories, such as numbers of cases of bronchitis; total Disability Adjusted Life Years (DALYs) or similar measures; and monetary valuation of DALYs. But the ability of DALY calculations to adequately represent health outcome is disputed: does a single monetary measure adequately represent the value of a DALY and should the value of a DALY depend on income? Three main options for assessing non-market impacts are available:

› Option 1: Apply the best available estimates of monetary valuations of all health and environmental impacts. This has the advantage of internal consistency and establishing a numerical estimate for any scenario, which is required for cost-benefit analysis.

› Option 2: Apply only the most established and least controversial valuations of non-market benefits, such as the externality prices for common air pollutants used in energy-sector analyses. In addition, report all major health and environmental impacts in their natural units, such as DALYs, and use qualitative assessments in parallel for impacts that do not easily lend themselves to quantification.

› Option 3: Avoid all use of monetary valuations of non-market benefits and report all market costs and benefits in monetary terms and health and environmental impacts in natural units. Avoid DALYs to avoid the ethical paradox of pricing the priceless values of life, health and nature.

For both mitigation and adaptation analysis, Option 2 is recommended, since it allows comparison with other studies using standard monetary values for some externalities and DALYs for

health impacts, while retaining essential information about impacts in natural units — an important element in communicating results to non-specialists. Both options 2 and 3 are preferable to option 1, since any attempt to monetize all costs and impacts would run the risk of producing a set of results that depend heavily on subjective measures, particularly in the areas of health and environmental impacts. Rather than embedding these measures in the impact estimates or assessment of likely effects, it is better to adopt an approach based on multi-criteria analysis — which underpins the MCA4climate policy evaluation framework (described in section 3) — at the policy scoring and ranking stage in evaluating and prioritizing climate policies.

Discounting

Given the long time-spans involved in analyzing climate policies, the discount rate that is applied to future costs and benefits of any climate-policy action makes a big difference to comparative costs and benefits. Discounting plays a major role in any economic analysis of costs and benefits extending over a period of several years. For conventional project analysis or investment decisions, it is appropriate to use an economic discount rate, based on the opportunity cost of investments in capital markets.

However, for public policy decisions, especially those with very long-term consequences, it is appropriate to use a social discount rate, reflecting society's preference for weighting present against future costs and benefits. several of questions have been raised regarding the choice of a social discount rate for climate-policy analysis, which are set out below (with recommendations on how to answer them).

Should future costs and benefits be discounted at all?

There is a long-standing debate about the use of discount rates. Some moral, philosophical and ethical arguments have been raised against discounting, as it favours the well-being of current over future generations. Critics have suggested alternatives such as summing undiscounted future quantities up to a fixed time horizon of, say, N years, and then ignoring later years (which, for a constant, unending data series, is mathematically equivalent to discounting at an annual rate of 1/N).

Our recommendation would be not to discount quantities that cannot be adequately expressed in monetary terms, such as many health and ecological impacts. However, since the practice of discounting is widely accepted, even in climate analyses, it is recommended to use discount rates for quantities that lend themselves to monetary valuation.

Should the discount rate be constant or decline over time?

Constant discount rates have long been the norm in comparing future costs and benefits. They simplify calculations and follow the logic of financial markets. There is a strong-case for their use in short or medium-term financial calculations. But for inter-generational public policy choices, there is less need for consistency with markets. Discount rates that decline over time have been proposed on two grounds: the results of psychological research suggest that individuals' preferences change over time; and uncertainty about future interest rates and growth rates. Declining discount rates are starting to appear in climate-policy analyses; for example, the UK government in its Treasury Green Book (HM Treasury, 2004) proposes their use for official approval of projects with long-term impacts.

It is recommended that the effects of declining discount rates be explored through sensitivity analysis using constant rates as the base case. This is a relatively straightforward task using spreadsheets. In view of the sensitivity of long-term calculations to the discount rate, it may make sense to analyze the implications of more than one discount rate scenario and even to back-calculate the discount rate at which a policy proposal 'breaks even' (i.e. discounted costs are exactly equal to discounted benefits).

What rate of return should be used?

There are two main approaches to discount rates, sometimes called 'descriptive' and 'prescriptive'. There is no correct approach: the choice depends on attitudes to inter-generational equity. With the descriptive approach, the appropriate rate is that which savers and investors actually apply in their day-to-day decisions; for investments with returns that are not correlated, or negatively correlated, with the broader market, the appropriate rate is considered to be the rate of return on risk-free assets such as long-term government bonds in developed countries, which typically averages 1% or less in real terms. Climate mitigation and adaptation actions have a higher return in scenarios where climate damages are severe, so they can be seen as social insurance against disaster, rather than ordinary profit-seeking investment. As is typical for insurance, their returns are uncorrelated or negatively correlated with the broader market. Thus the risk-free rate of return is the recommended choice under the descriptive approach to discount rates.

The prescriptive approach involves the use of the so-called social discount rate, which is the sum of the rate of pure time-preference and the rate of increased welfare derived from higher per-capita incomes in the future (the so-called Ramsey equation, after the 20th century economist Frank Ramsey who came up with it). The rate of pure time preference is the discount rate that would apply if all generations were known, with certainty, to have identical incomes and resources. We recommend the use of a near-zero rate of pure time preference on the grounds of the ethical principle that all generations are equally important; this is in line with the position taken by the Stern Review (Stern, 2006). The income-based component of the discount rate is a multiple of the rate of growth of per capita consumption. This reflects the principle that the marginal benefit of another dollar of income is lower for richer people and therefore, benefits to richer, future generations should be discounted. Many studies have used values in the range of 1% to 2%, which is our recommendation.

An uncertainty-based component of the discount rate is not part of the simple Ramsey equation, but needs to be taken into account in analysis of climate policies. This component is a negative multiple of the variance in future growth rates. In other words, the more uncertain the future is, the lower the discount rate should be to reflect the greater need for precautionary savings in a more uncertain world. Failure to include this in the Ramsey equation amounts to assuming that the future is known with certainty.

Time horizon of the analysis

The time dimension of the climate-change problem is crucial. Climate science deals with long time horizons of at least 100-200 years. Robust climate policy needs to take account of long-term climate changes. Climate policy on both mitigation and adaptation will need to adjust as our understanding of the mechanics of climate change improves, as this will affect the costs and impacts of responding to it. Projecting far into the future also helps to improve our understanding of potential links with fiscal sustainability. But the longer we project into the future, inevitably the larger the uncertainty in estimating the costs and impacts of policy action. Policy analysis can focus on different time horizons:

› Option 1: The short term; for example, up to the year 2020. The advantage of this approach is that more information and modelling applications are available. Moreover, it minimizes the importance of the choice of discount rates and the treatment of uncertainty, avoiding those difficult questions. However, much of the economic, social and environmental impact of policies could be seen after one or even two decades.
› Option 2: A time horizon extending to 2050 at least and up to 2100. This would allow for a more complete assessment of the extent to which greenhouse-gas stabilization targets could be met, how effective adaptation to climate change could be, potential changes in long-term economic cycles and

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technological innovation, and the potential for co-benefits. However, as the time horizon increases, the greater the uncertainties will be.

› Option 3: A time horizon up to 2200. Whilst this would allow socio-economic analysis over the time spans relevant to climate science, the uncertainties may be too large to generate any reliable results.

Option 2 would be preferable for long-term planning of mitigation policies. However, the short-to medium-term impacts of long-term plans also need to be explored. For adaptation, both options 1 and 2 are reasonable choices. Many policies have a short-term focus, yet there is need to consider longer-term adaptation measures, which can have time horizons up to 2050.

Developing baseline projections

Sound climate policymaking must be based on reliable projections and robust analysis of the drivers of greenhouse-gas emissions and sinks and their links to future climate change. This must be underpinned by climate and economic modelling. An important first step is the construction of a 'baseline' or 'business-as-usual' scenario that projects emissions trajectories, climate damages and other relevant macro-level developments on the assumption of no change in climate policy beyond that which has already been decided and is expected to be implemented. This 'business-as-usual' scenario maps out the costs and benefits of inaction — that is, choosing not to implement any new climate policies. Starting from this baseline, it is then possible to examine the likely effects of a proposed change in policy at a global, regional, national or even local level. Specifically, baseline analysis allows policymakers and other stakeholders to:

› Predict underlying trends in greenhouse-gas emissions by source, including agricultural and land-use sources.
› Demonstrate links between emissions and the development of the energy system, especially where emissions are rising quickly.
› Help in assessing how far a policy or project takes us beyond business-as-usual, a concept referred to as additionality.

National economic models need, at a minimum, to be able to capture the main drivers of emissions and related environmental impacts. They also need to represent interactions with the rest of the world economy, including through trade and technology transfer (though usually in a stylized and fairly simple manner). Some relevant baseline projections already exist at the global level, such as the International Energy Agency's annual World Energy Outlook, and

in many cases at the national level, such as economic projections.[14] For many countries, however, detailed climate-policy analysis may require the development of national data sources. In practice, many models focus primarily on the costs and benefits of mitigation options. This is in part because widespread recognition of the importance of adaptation is comparatively recent, and in part because adaptation is more difficult to model.

Climate modelling involves many choices, few of which have definitive right or wrong options. We describe below a number of issues related to these choices in preparing baseline projections, concerning model design and data inputs, specifically: which macroeconomic variables to consider; how to incorporate national baseline greenhouse-gas emissions and which sectors to analyze; macroeconomic modelling of the public sector and financial markets; and modelling environmental impact, including climate changes and forestry.

Critical macroeconomic variables to consider

The main macroeconomic variables that need to be taken into account in developing a baseline set of projections include the following:

› Population, by sub-national region where appropriate.
› Distribution of age, race-ethnicity and income.
› Health status of the population, such as distribution of major diseases.
› Employment by economic sector.
› Gross domestic product, and the contribution of energy-intensive economic sectors to it.
› Investment.
› Exports and imports.
› Prices of fossil fuels.
› Taxes and other government policies that affect the prices of fuels or emissions.
› Prices and quantities of key commodities impacted by climate change.

In practice, the more of these factors that are incorporated into the modelling framework, the more resource-intensive the exercise will be. An alternative is use a basic set of variables, such as population, GDP, employment, and emissions by economic sector. The appropriate choice depends on the available data and modelling resources. Whatever that choice may be, the projections of each variable, where they are treated exogenously, should ideally come from the same source and be derived consistently from one standard set of underlying assumptions. That data should be adjusted for inflation. Consideration also needs to be given to the method of comparing economic data across countries: market

14 Some leading sources of international data and projections can be found in Annex B.

exchange rates, whereby national monetary values are converted to a single currency (usually US dollars) at the prevailing exchange rate is the appropriate basis for cross-country comparisons of economic activity in sectors where international trade plays a big role, for example production of oil; purchasing-power parity is a better basis for comparing activity in non-traded sectors, such as locally consumed services.

Incorporating national baseline greenhouse-gas emissions

Most national climate-economic models include estimates of national baseline greenhouse-gas emissions. Data for an initial year are taken from national emissions inventories. Future years' baseline emissions may be modelled in one of two ways: endogenously, by combining economic projections with information about the emissions intensity of national industries; or exogenously, using projections by national environmental or energy agencies. In either case, models commonly distinguish between emissions from fossil-fuel combustion, from agriculture and forestry with existing land-use patterns, and from land-use change. Modelling emissions endogenously within the model allows for the greatest consistency of economic and climate projections. However, projections generated endogenously should be cross-checked for accuracy against projections made by national agencies.

Number of sectors to analyze

The degree of aggregation or disaggregation is another modelling choice for which there is no single right answer. Many global models are highly aggregated, in order to focus on the big-picture interactions between climate change and long-run economic growth. On the other hand, some national economic models, such as input-output models, may represent the short-run behaviour and interactions of hundreds of economic sectors. Between these extremes, there are many useful models with a moderate number of separate economic sectors. More sectors allow more precision and detail; more aggregation (i.e. fewer sectors) clarifies the understanding of the problem as a whole. Using a highly aggregated macroeconomic model with up to three economic sectors is useful primarily for initial exploration; while it may provide a starting point, it will not generally produce adequate analyses of the interactions of climate and the national economy. On the other hand, applying a highly disaggregated model, representing a large number of separate sectors would be prohibitively expensive, in time and money, if a new model has to be created. It is appropriate only when a detailed economic model, such as a national input-output model, is already available for use. In most cases, the preferred alternative would be to a compromise by modelling an intermediate number of economic sectors (perhaps

between 10 and 30). In this case, it is important to distinguish between sectors most vulnerable to climate change, such as agriculture, fishing, forestry, tourism, and construction; the most emissions-intensive sectors, such as transportation, electricity generation, mining, oil refining, agriculture (especially livestock), and heavy industry; and the most trade-affected sectors (top export and import industries).

Government budgets

The effects of government fiscal and monetary policies can be subsumed into GDP projections, except where important targeted investments in emission-intensive sectors are expected. Depending on the areas in which the public sector is active, it may be important to examine government spending on transportation, electricity and other infrastructure; management of public oil and gas deposits, forests, and other natural resources; and energy-efficiency initiatives, emissions taxes, and other climate and energy policies. In general terms, government spending can influence the level of employment, the rate of economic growth, and the balance of trade. Changes in tax and subsidy incentives can play an important role in climate policy, through such measures as the removal of fossil-fuel subsidies, the introduction of subsidies for renewable energy and tax incentives for low-emission vehicles. The structure of the available economic models, as well as the complexity of the modelling effort, will affect how best to treat the public sector. Some government activity is directly tied to economic growth: tax revenues normally increase as the economy expands, while welfare payments normally increase during economic downturns. These components of the public sector should be endogenous in an economic model. Other government activity, such as expenditure on infrastructure or exploitation of natural resources, is more likely to be exogenous, driven by actual policy choices.Including government activities only as a source of emissions is most appropriate to a very simple climate-economics model. The most complex models will require government activities to be modelled fully, including investment in infrastructure and endogenous economic effects related to taxes and transfer payments (such as unemployment or welfare support). But in most cases, the preferred option would be to include government emissions as well as the likely effects of key policy initiatives related to climate and energy, so that the main effects of government on emissions are included without making it necessary to incorporate a level of detail that would be inconsistent with other parts of the model.

Financial and monetary sectors

The financial sector, along with monetary policy, plays a central role in determining interest rates and exchange rates, which affect economic growth and trade. The financial crisis of 2008 provided a clear illustration of the importance of the financial sector for economic growth and, hence, greenhouse-gas emissions. In a detailed economic model, financial institutions and monetary policies play an important part in determining the pace of growth.

In a model focused more specifically on climate finance and investments, the policies of lending institutions toward energy efficiency and renewable energy may be important; the transition to a more sustainable economy could be eased by 'green finance', or blocked by its absence. Many economics models, however, do not include specific financial data or a separate representation of the financial sector. Instead, these models use projections of GDP and its components that take into account the likely future impacts of financial and monetary policies. In most cases, national climate-economics models will need to use the standard projection of GDP and its components made available by the national economic bureau. In some case, it may be possible to make strategic corrections to standard GDP projections, based on assumptions about financial and monetary policy that enhance consistency with other projections used in the climate-economics model. Only the most complex models ought to attempt to fully incorporate a financial sector and government fiscal and monetary policy into the model, including public investments in energy efficiency and renewable energy.

Incorporating climate damages

Climate damages include reductions to the annual output of many vulnerable sectors and large-scale replacement costs for infrastructure damaged by flooding and other serious climatic effects. Economic models of climate change often calculate damages as a fraction of output, either for the economy as a whole or for vulnerable sectors such as agriculture. Based on primary research on climate damages, these models often specify a relationship between output losses and changes in temperature (or, in some cases, changes in precipitation or sea level). Thus, a scenario with greater climate impacts would project greater economic losses. However, damages calculated in this manner result in an underestimate of the welfare cost of climate change because they fail to account for the disutility of having to bear the risks of climate change (even if the potential damages never actually occur).

The expected magnitude of damages and their relationship to climate change are still being debated, so there is no consensus about the appropriate estimates to use in economic modelling. Some models have predicted net benefits to agriculture from the first few decades of climate change, either for the world as a whole or for high-latitude regions. But newer research on agricultural damages has led many economists to

reject this view. There is, however, virtual unanimity that agriculture, like other sectors, will suffer from climate change in the long run.

Inclusion of climate damages in an economic model requires that they be assigned prices. Some climate damages are naturally expressed in economic terms, but others, such as damages to human health and the natural environment, do not have prices. There are three main options:

- Option 1: Measure climate damages as the expected reduction in vulnerable sectors' contribution to GDP, especially agriculture, fisheries, forestry, and tourism.
- Option 2: Include both expected GDP losses in key sectors and the expected replacement cost of buildings and other infrastructure damaged by climate change.
- Option 3: To these estimates of economic losses and replacement costs for damaged infrastructure, add a monetary value for damages to human health and the natural environment.

Option 1 leaves out what are expected to be some of the most serious economic costs of climate change, including damage to infrastructure from coastal flooding and higher temperatures (especially in high latitudes). Option 2, which includes both economic losses and infrastructure costs, will provide the best climate damage estimates for most models. It will be important, however, to report model results along with a clear discussion of what is and is not included. While option 2 includes only market damages, option 3 has the added category of monetary values for non-market damages. This is a complicated area of modelling, where errors, conjecture, and implicit normative choices can easily dominate results. Often, a separate discussion of expected impacts to health and environment will be of more use to decision-makers than model results that lump together market and non-market effects.

Forestry and deforestation

Forests have an important role in several aspects of climate modelling: changes in forest coverage due to climatic factors or land-use changes will impact on emission sequestration, while investment in afforestation is expected to be a critical component of global mitigation policy. Forests sequester large amounts of carbon, which is removed from the atmosphere as trees grow, and 'stored' in living trees for decades. Deforestation releases much of this sequestered carbon when trees are cut down; deforested soil also loses carbon over time. Many studies, including the Stern Review, have concluded that reductions in deforestation, or increases in afforestation, are among the world's lowest-cost options for greenhouse-gas mitigation (Stern, 2006). This is of particular importance in countries with large tropical forests. For countries where forestry is important to greenhouse-gas inventories, there is a need to prepare baseline projections of forestry sequestration and deforestation (though forest protection and forest-based industries are generally quite separate from the principal sources of fossil-fuel emissions). At the very least, climate-economics modelling needs to include a simple forestry module, in which forest sequestration is driven by assumptions about land-use changes, including deforestation and afforestation, which in turn would be a function of economic growth. For nations with significant current-day forest sequestration and future afforestation potential, it may be appropriate to link a detailed forestry model — most likely an existing national forestry model — to the main climate-economics model. This decision would depend on the availability of an existing national forestry model that can be adapted to use in climate-economics modelling.

Interactions with the world economy

For nations with large economies that account for a large share of global greenhouse-gas emissions, it is essential to model the two-way interactions between the world economy and climate system on the one hand, and domestic economic output and emissions on the other hand. At a global level, there are two major interactions between economic activity and the climate system. First, emissions from production and consumption lead to climate change, which causes economic damages; second, investment in abatement reduces emissions, and therefore slows climate change, which in turn could accelerate long-term economic growth relative to a business-as-usual. Investment in adaptation can also reduce climate damages, but does not affect the pace of climate change, as discussed above. In a global climate-economics model, the interplay between these forces should be at the core of the model's dynamics.

For a larger country, or for a major exporter of oil or other important commodities, it may be appropriate to model these complex interactions with the world economy. The largest developing countries and emerging industrial economies may be big enough to influence world markets and prices. In such cases, the model needs to be sufficiently complex to represent the two-way interactions.

Interactions with the energy system

The energy system, both global and national, also has important interactions with national economic growth and greenhouse-gas emissions. Indeed, energy use is the source of the great majority of emissions. Including one or more separate

energy sectors in climate-economic models is essential to achieve a comprehensive representation of the consequences of national policy choices. Depending on the level of detail in the model, the energy sector may be treated separately, including electricity, heating fuel, and energy used in transportation and industry. Energy prices, taxes and subsidies influence energy use. Total energy demand and the composition of energy sources used are likely to change as temperatures rise, reducing the need for heating fuels and increasing the need for electricity to run refrigeration and air-conditioning systems.

In the short run, the key variables to model are often the use of different modes of transportation and the energy efficiency of each mode, and the demand for electricity and mix of fuels used to generate it. For later years, in a model with a longer time horizon, technological development will determine the rate at which new energy options become available and the projected prices for various energy sources. Much will depend on the model's assumptions about oil supplies, market power of oil producers and the availability of unconventional sources of oil, such as shale and tar sands, which can be more environmentally damaging than conventional sources.

In most cases, it would suffice for national modelling to treat energy use separately from other economic activities, but assume an exogenous decrease in carbon intensity over time and a simple relationship between temperature change and energy use. This approach offers an appropriate level of detail while avoiding undue model development costs. A more sophisticated approach, which may be beyond the means of most countries, would be to model both carbon-based and zero-carbon energy sources separately from other economic activity, and introduce endogenous technological improvements, so that greater investment in alternative energy reduces the relative cost of similar future investments.

Dealing with risk and uncertainty

Defining risk and uncertainty

Risk and uncertainty are inherent characteristics of both climate science and the formulation of climate policies. Climate and economic systems are characterized by long time lags and complex causal connections, and long-term outcomes are inevitably very uncertain. For analytical purposes, it is helpful to distinguish between risk and uncertainty. In conventional economics, risk refers to events with known probabilities, while uncertainty refers to events with unknown probabilities (sometimes called 'Knightian uncertainty', after the economist Knight, 1921). In the field of risk assessment, on the other hand, risk is often interpreted as combining the likelihood of an undesirable event and its consequences (Daneshkhah 2004), while uncertainty refers only to questions of likelihood. In this definition, there are two types of uncertainty: known uncertainty, where the distribution of probable outcomes can be deduced from established principles or determined from empirical research; and unknown uncertainty, referring to cases where the distribution of probable outcomes cannot be determined (equivalent to Knightian uncertainty).

The risk assessment definition of risk and uncertainty is most appropriate for climate-related analysis. In this approach, known uncertainty can be divided into two inter-related categories:

- Internal uncertainty, which stems from a lack of sufficient knowledge about the phenomena under study and can be reduced through improved analysis and additional empirical research (Daneshkhah, 2004).
- External uncertainty, which arises from outside the field of study, and is not reducible through additional effort in the same area, although it can be quantified. External uncertainties are sometimes referred to as aleatoric or chance events, or as irreducible uncertainties (Daneshkhah, 2004).

While internal uncertainties are relevant for both mitigation and adaptation assessments, external or aleatoric uncertainty applies most directly to adaptation, in the case of the natural variability in the climate and weather system resulting from natural hazards and extreme events. Known uncertainties are common in climate assessment. They include the links between anthropogenic emissions, atmospheric concentrations, radiative forcing and climate responses, particularly extreme weather or catastrophic events. Socio-economic system uncertainties include trends in demography, health projections, economic growth, technological change, fluctuations in energy prices and the rate of anthropogenic emissions.

Climate scenarios address uncertainty by presenting a coherent, quantitative picture of a possible future, driven by a set of scenario assumptions (see Economic analysis of climate-policy options, above). With this approach, there are several methods available to analysts to quantify the uncertainties in the chain of causal models linking the climate to population health, ecology and the environment. These include deterministic and probabilistic methods:

The deterministic approach to uncertainty is popular in cost-benefit analysis. It involves converting the range of possible outcomes to a 'certainty-equivalent' estimate, based on an assumed probability distribution which is used to construct a weighted average of likely outcomes. This technique converts known uncertainties into deterministic 'expected values'. The starting point for this procedure is the implicit assumption that the probability distribution of possible outcomes is known. In some cases, however, the adoption of a familiar probability distribution, such as the normal, or bell-curve, distribution, is based on little or no information, thus inappropriately converting an unknown uncertainty into an apparently known uncertainty.

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The probabilistic approach is more suitable for large, rare or unique events, such as the long-term evolution of the climate system — especially given the expectation of catastrophic damages and deeply uncertain probabilities associated with worst-case outcomes. Under such conditions the expected value of an incremental reduction in emissions could, technically speaking, be infinitely large (Weitzman 2009). Extreme climatic events, or climate catastrophes, may have low probabilities of occurrence but very high, discontinuous, and irreversible impacts if they do occur. Use of heavy-tailed distributions is crucial in modelling the uncertainty in low-probability, high-impact events. The threat of such events, which become more likely as emissions increase and global warming accelerates, may call for different approaches to climate policy and analysis.

Options for analyzing uncertainty

The extent of uncertainty involved in climate assessment is daunting. Despite the wide range of possible outcomes, many adaptation measures, such as improvements in sanitation and public health, may make sense as they would be desirable under virtually any climate scenario, i.e. they may fall into the category of no-regrets policies (see above). However, the value of other policy options depends critically on climate uncertainties. For example, should planning for a river basin include large-scale investments in preparing for floods or for droughts?

Dealing with uncertainty is an inescapable part of climate-policy planning, particularly for the low-probability, high-cost risks that emerge from global climate projections. How should a national climate assessment address the uncertainty surrounding both normal and catastrophic risks? Furthermore, how should such an assessment treat the uncertainties about key macro-level indicators that inform the analysis? The deterministic approach is best suited to answering the first question, with the probabilistic approach is more suited to answering the second. Two main options are available:

- Option 1: For climate-related uncertainties, assign the best available guesses at the relevant probabilities to all possible outcomes and calculate the certainty-equivalent value, or weighted average. For macro economic uncertainties, carry out a sensitivity analysis that would look at a few subjectively chosen cases. This produces a single numerical 'bottom line' estimate, weighting rare events based on their likelihood as well as their magnitude of risk.

› Option 2: For climate-related uncertainties, perform analyses and calculations for at least two distinct scenarios, one representing most likely outcomes, and one representing credible worst-case risks. For macro economic uncertainties, carry out a fully fledged uncertainty analysis based on robust statistical techniques examining multiple possible values or pathways. The available information typically does not support precise estimates of probabilities of the worst-case outcomes included in the second climate scenario.

In the case of mitigation, option 2 is generally the recommended approach. For climate-related uncertainties, option 2 provides a better way to reflect uncertainty and worst-case risks, as arbitrary guesses at unknown probabilities (which are needed for option 1) are not particularly helpful in cases of acute uncertainty, which is typical in climate analysis. For macro economic uncertainties, option 2 is preferable whenever the necessary expertise is available. It is also important to address the uncertainty in policy selection when comparing alternative climate policies for decision-making. This could be done using either deterministic or probabilistic approaches. In the case of uncertainty in decision-making with catastrophic risks, normal decision analytical methods based on expected utility theory are not appropriate, because they are insensitive to low-probability, high-impact events. For adaptation, a combination of options 1 and 2 is likely to be the best approach. While option 1 is desirable whenever it can be applied, it has demanding data and analytic requirements. For example, for the impacts of extreme events, a probabilistic approach is necessary to account for fat-tailed events (where the probability distribution deviates from the norm), yet this would require data on daily variability, rather than the more frequently available monthly or annual averages. Given these limitations, the comparison of most likely and worst-case scenarios under option 2 may be all that is possible in practice.

Evaluating fiscal implications

Policies to mitigate and adapt to climate change potentially have significant implications for the public finances, both through their direct impact on public spending and tax revenues, and their indirect impact on economic activity more generally (which affects spending and tax revenues). Of all policies for the mitigation of climate change, the use of economic instruments has the most obvious relevance for a country's fiscal position and sustainability, because they can raise revenues as well as (like other instruments) change economic structure and incentives.

The main economic instruments than can be used to mitigate climate change include:

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› Energy and carbon taxes and charges.
› Trading schemes, especially CO_2 emissions trading (covering industrial emissions).
› Feed-in tariffs and renewable-energy obligations.
› Subsidies, either environmentally friendly or harmful subsidies (both types have a negative effect on the public finances but different climate implications).
› Payments under the Clean Development Mechanism (CDM) or Joint Implementation (JI) introduced under the Kyoto Protocol.
› Payments (currently being negotiated) for ecosystem services, such as those being negotiated for the Reduction of Emissions from Forest Destruction and Degradation (REDD), and REDD Plus, which also includes enhancing existing forests and increasing forest cover.
› Green fiscal reform, which entails a systematic shift in the tax base away from taxes on incomes and profits (sometimes characterized as 'goods') towards taxes on resource use and pollution (sometimes characterized as 'bads')

The different types of economic instruments to address climate change have very different implications for fiscal sustainability, which need to be carefully considered by governments. Some may generate state revenues (taxes and charges and through the auctioning of emission allowances as part of trading schemes, receipts from CDM, JI or REDD), while others may involve spending them (subsidies, payments under the CDM, JI, or REDD). Carbon and energy taxes, and auctioned tradable permits, raise revenue, which allows increased public expenditure or the reduction of other taxes. However, these revenues change over time, as carbon emissions or energy use changes. Governments need to assess how such revenue streams will change over time to ensure that they continue to receive the revenues they need. The take-up of subsidies needs to be projected and carefully monitored to ensure that they remain affordable. Finally, it may be that the government is already providing environmentally perverse subsidies (i.e. subsidies that effectively increase carbon or other greenhouse gas (GHG) emission. Removing such subsidies may yield an economic as well as an environmental dividend. This, too, should be assessed.

Compared with mitigation policies, adaptation policies more often involve public spending, for example, on infrastructure, coastal protection and early warning systems etc. The level and nature of these public expenditures are crucial to fiscal sustainability.

Modelling baseline fiscal sustainability

Governments need realistic short-term projections of public revenues and expenditures, and plausible projections as to how these will develop in the future. Clearly the further into the future the projections go, the more uncertain they become. Governments should distinguish between the short term, say three months to one year, over which time outcomes should be carefully monitored; the medium term (one to three years ahead), when underlying trends should be identified, perhaps through econometric techniques (see below); and the long term (more than three years ahead), when a much wider range of possible outcomes need to be considered.

Fiscal systems vary enormously across countries, as do the levels, types and sophistication of analysis and projections that are carried out. However, for countries to have any idea of the impact of climate change or climate change policies on their fiscal system, they must have a model of their fiscal system and some projections of how the public finances will develop in the absence of climate change. This model needs to include at a minimum projections of economic growth, population and demographic change, investment, government taxes and spending and trade. Of critical importance in assessing baseline fiscal sustainability is the type of economic model to use. Most work in the areas of the economics of climate change and fiscal policy assessments has been carried out using two types:

- Macro econometric models: These models use econometrics (the combination of economic theory and empirical analysis based on large historical datasets) to identify past trends in an economy, and then project those trends (perhaps modified in some way) into the future. The major advantage of econometric models is that they incorporate economic theory, are consistent with and can make use of economic accounting frameworks, and are based on real data about the economy. Their major disadvantage is that they are data intensive.
- General equilibrium economic models: This kind of model assumes that the economy will develop in a broadly balanced way, with clearing markets and economically rational actors. The model is calibrated to represent the economic outcome for a single year and is then allowed to develop into the future according to theoretical relationships and any exogenous assumptions (such as population growth) that have been specified in it. The advantage with using this type of model is its strong theoretical basis and its ability to give insights into the longer term (more than 20 years). This means that the model can be more easily linked to climate models. The disadvantage is that the model is not based on empirical data and its validity depends entirely on that of the assumptions.

The utility of a model depends not only on the validity of the relationships and assumptions embedded in it but also on the maintenance of an expert team that can run, develop and interpret that model in the light of current events. Econometric models are generally to be preferred for short- and medium-term analysis, including the effects of policies, which makes them the preferred option for analysis of fiscal sustainability.

Mitigation ancillary costs and co-benefits

Policies to mitigate greenhouse-gas emissions may lead to a range of secondary (or ancillary) benefits and costs. Potential benefits include the economic gains from lower imports of fossil fuels that may result from increasing energy efficiency or by substituting fossil fuels with domestic low-carbon energy sources. Such economic impacts will have fiscal implications. In addition, collective mitigation efforts will not only reduce the damage from climate change but also reduce the need to spend revenues for adaptation measures, the implications of which for public finances could be very considerable. Ancillary costs from the mitigation of climate change include any negative environmental impacts from substitutes for fossil fuels (e.g. nuclear waste from nuclear power or technology imports where the new carbon-free sources cannot be produced domestically). These impacts too need to be assessed for their possible impact on the public finances. There are three main approaches to assessing these ancillary impacts:

- Option 1: A bottom-up, often partial equilibrium, approach. This is used to assess impacts in purely physical terms, such as reduced concentrations of air pollutants and improved health. The implications of these changes for the public finances would then need to be calculated, in terms of the extra income and, therefore, extra tax revenues from improved health and productivity, and a corresponding reduction in spending on public health.
- Option 2: A full, top-down economic model. This would assess the interactions throughout the economy and the economy-wide fiscal effects, based on the bottom-up calculations of option 1. If adequate resources were available, the model outputs could be further coupled to bottom-up physical or other types of models to capture specific secondary effects.
- Option 3: Monetary valuations of non-market effects (for example, the well-being effects from improved personal health). Such effects will not have a direct impact on the public finances, but it would, in principle, be possible to assign to them a monetary valuation (see the section, Monetary valuation and non-market impacts, above). However, the valuation of non-market costs and benefits can be a difficult, expensive and controversial exercise, requiring substantial expertise and research inputs.

Option 1 is essential if any insight is to be gained into the size of the ancillary benefits of mitigating climate change. It is desirable to pursue option 2, but being able to do so depends on having an appropriate macroeconomic model and adequate data. Many developing countries may not have such a model, although as noted earlier, it is very difficult without such a model to get adequate insights into the implications of climate policy for the public finances. Whether to proceed to option 3 depends on the specific issues to be addressed and available resources.

The stimulation of mitigation technology

Low-carbon technologies will need to be developed and deployed to reduce greenhouse-gas emissions. Some new technologies, especially those related to energy efficiency, are already cost-effective, but are not taken up because of a range of market failures. These can be addressed by government policy. Where a policy is successful in encouraging the deployment of such technologies, the country may derive competitive advantage from their deployment and export of these technologies. Depending on the countries' fiscal system, this could generate substantial tax revenues. Countries need to assess the prospects of such developments in order to estimate their fiscal impact. This requires the use of macroeconomic models as described above. However, it is possible to assess the different effects arising from different policy instruments that may be used to stimulate the uptake of new technologies. It is easiest to model public policy support for new technologies through economic instruments (described at the start of this section) and policymakers should attempt this. Subsidies, in particular, may have negative fiscal implications in the short to medium term, but positive impacts in the longer run as export of these technologies may increase. It is harder to model the effects of regulatory measures, such as standards and mandates, which can also be used to stimulate the diffusion of new technologies. While the direct budgetary implications of this approach may be limited, as regulations specify the technologies to be used, their wider economic effects may have significant fiscal impacts. Where regulatory measures lead to a faster uptake of low-carbon technologies than market-based instruments, then the longer-run positive impacts on the tax base may be greater. Although it is far from straightforward, consideration should be given to modelling these impacts, and those of other types of policy instrument, in order to identify the most cost-effective policy approach.

Mitigation technology transfer and use of the Kyoto mechanisms

Direct financial support from the developed to developing countries to support the latter's mitigation and adaptation actions, including via the purchase of certificates under the clean development mechanism and joint implementation, will inevitably have implications for all countries' fiscal positions, which should be assessed. Contributions to international funds, such as the newly created Green Climate Fund, may have negative budgetary implications for donor countries. For the developed countries, the fiscal impacts should ideally be assessed against the implications of the countries that are to receive support achieving their emissions targets through domestic action (which could be more expensive). For the developing countries, the fiscal impacts could be positive, through the beneficial effects on their economies.

A first estimate of the significance of such transfers for fiscal balances can, of course, be derived by calculating their absolute size, and then considering this in relation to the overall size of the economy. The advantage of this option is that it is relatively simple, and the data are likely to be readily available. Its disadvantage is that it fails to capture the wider economic impacts of the transfers. Where the transfers are large, their full impacts can only be assessed through the use of macroeconomic models. The model should be sufficiently detailed to allow, for example, the impact of the transfers on specific economic sectors in the receiving country to be assessed. Care should be taken to take into account the use of the funds by the receiving country over time, so that the implications of the transfers for international trade are also taken into account. However, this would require a fairly sophisticated model.

Adaptation policies

Most adaptation measures will have fiscal implications, mainly through public expenditure. These need to be taken into account in evaluating and prioritizing policy options. At a minimum, an assessment of the fiscal implications should include not only public expenditures incurred when adapting to climate change but also the public expenditures saved and/or government revenue loss avoided due to climate damages avoided by the adaptation measures. As with some of the issues discussed above, the full economic, and therefore fiscal, implications of implementing adaptation actions can be assessed only by using a macroeconomic model. Such an assessment is highly desirable, but will depend on developing adequate analytical and modelling capacity.

Creating mechanisms for long-term fiscal planning

There are powerful arguments for countries to engage in long-term fiscal planning in relation to climate change, though the uncertainties involved mean that such planning is very challenging.

For most countries, it will require new institutions and new tools for modelling and analysis, incorporating the impacts of different events of different severity arising from climate change, and or government responses to these. So far, even for industrial countries with the institutions, models and requisite expertise, such planning is in its infancy. The annual budgetary process, which is still dominant in most countries, is completely inadequate for such considerations. Bodies like the OECD are advocating multi-annual budgeting to promote fiscal stability even without any reference to climate change, and the uncertainties in the prospects of climate change considerably reinforce their arguments. Another example is the long-term budget of the European Union (multi-annual financial framework) to account for investments in pan-European public goods.

Multi-year budget forecasts need to firstly establish a framework for fiscal sustainability in the absence of climate change, giving insights into the evolution of such variables as expenditure, income, and any financial deficit under existing law and a given economic framework.

It should include a medium-term expenditure forecast, and should be explicitly constructed to overcome the all-too-common failure to link policy, planning and budgeting adequately. It should also span elections and, to reduce political bias, should be carried out by an independent institution such as, in the UK, the recently established Office for Budgetary Responsibility. The impacts on fiscal sustainability of climate change, and of measures to address it, can then be evaluated against this baseline. This will involve the consideration and modelling of multiple and pervasive uncertainties, as described above. Different scenarios should be built that span the range of likely climate effects, with sensitivity analysis around the major impacts to see which have the most effect on fiscal sustainability.

Finally, measures to increase fiscal sustainability should be proposed and, if possible, modelled in the same framework as that used for the baseline and impacts from climate change and climate change policies. Such policies may include the imposition of carbon taxes or auctioning of permits to raise revenues; or the imposition of a requirement for people to take out private insurance against climate-change impacts (where it is being offered) to reduce the exposure of government revenues to these events. The purpose of such scenarios is to provide policymakers, especially Ministries of Finance, with insights into the implications for fiscal sustainability of climate-change and related policy responses, so they can prepare for them.

Measurement, reporting and verification

Measurement, reporting and verification (MRV) has emerged as a central issue in international climate negotiations. It

is seen as essential to the effective tracking of progress by parties to the UN Framework Convention on Climate Change in meeting their national commitments and achieving the Convention's overall goals. In particular, it is seen as a way of providing a basis for mutual accountability between developed and developing country parties, to ensure that both sides take appropriate mitigation actions and commitments, and that the developed world provides support for the actions of developing countries The 2010 Cancún Agreements involved important steps toward an operational system for MRV by agreeing to establish an international registry for financial and technical support, and enhance regular reporting and review processes for mitigation actions.

MRV of mitigation actions and monitoring and evaluation systems for adaptation actions are related in that both can play a role in tracking climate finance. Some of the problems in monitoring and evaluating adaptation actions are common to MRV of mitigation actions. These include dealing with uncertainty, establishing baselines, attributing cause and effect and identifying appropriate performance measures or indicators. Others are more specific to adaptation, such as determining adaptive capacity. With careful design, monitoring and evaluation systems for adaptation and MRV systems for finance could be made complementary to each other, and could promote efficiency by drawing upon the same data resources. The Framework Convention and the Kyoto Protocol contain a number of provisions relating to the MRV of information on national climate actions. Under the Convention, all parties are required to submit national communications and national greenhouse-gas emission inventories. However, the requirements on what type of information that must be reported and how often differ substantially between Annex I countries (developed countries and former Soviet Union states) and non-Annex I countries (developing countries). Reporting requirements for Annex I countries were strengthened under the Kyoto Protocol and the Cancún Agreements, though much remains to be agreed to implement fully those decisions.

In light of the existing climate regime, there are a number of practical issues concerning MRV and monitoring and evaluation that national governments need to take into consideration in formulating their mitigation and adaptation actions. These issues include:

› Reporting of mitigation actions: a critical question facing policymakers in developing countries is what level of aggregation or detail and type of information is appropriate in reporting mitigation actions? At a minimum, the information on mitigation actions reported should be sufficiently detailed and presented in such a way as to enable third parties to understand what types of mitigation actions are planned or have already been taken, what their impact is expected to be across different sectors and how that impact has been projected — where possible, in quantitative terms.

- Measurement of mitigation actions: accurate measurement of mitigation actions and their effects on emissions is crucial to providing an accurate picture of the overall national mitigation efforts. The appropriate degree of aggregation and sophistication of the measurement techniques will depend on the scale of the emissions reductions that are expected to be achieved, the type of commitment (NAMA or quantified target), the types of policies and measures as well as the technical capacity of the government to carry out this exercise.
- Institutional changes to improve MRV of climate policy actions: meeting the additional requirements for MRV of mitigation actions under the Cancún Agreements will undoubtedly be very challenging for many countries. This can be achieved through internal capacity building (technical capacity and human resources), reliance on outside expertise, or some combination of the two.
- Reporting of climate finance: a pressing issue facing developing countries concerns the type of information on financing requirements that should be reported to best enable lenders to meets those needs. The type and amount of information that ought to be reported on financing needs will depend to a large degree on national circumstances and institutional capacity, and the nature of the project in question. In general, the information reported needs to take account of the way in which donor countries prioritize their financing.
- Management and monitoring of climate funds: donor governments need to be confident that the funds provided for climate mitigation or adaptation actions are properly utilized and well-managed. In order to obtain such funds, it is therefore essential that recipient governments demonstrate transparency and accountability in their use.
- Dealing with risk and uncertainty in monitoring and evaluating adaptation actions: monitoring and evaluation systems will need to be a prominent feature of adaptation strategies and projects as they evolve. For those systems to be effective in a context of enormous uncertainty about the impacts of climate change, they need to be consistent with results-based management, maintaining flexibility and encouraging learning.
- Measuring the success of adaptation actions: given all the uncertainties surrounding climate change, it is vitally important that national governments devise good measures and indicators to help measure and evaluate the success of both the adaptation process and its outcome in enhancing adaptive capacity. These indicators need to be used to track progress over the long term.

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MCA4climate Annex A: References

Annex B: International sources of data and projections

Emission Database for Global Atmospheric Research (EDGAR):
www.edgar.jrc.ec.europa.eu/index.php

Food and Agriculture Organization:
www.fao.org/corp/statistics/en

International Energy Agency:
www.iea.org

Penn World Table:
www.pwt.econ.upenn.edu

United Nations Development Programme:
www.hdr.undp.org/en/statistics/data

UN-DESA Population Division:
www.esa.un.org/unpp

US Energy Information Administration:
www.eia.doe.gov

World Bank:
www.data.worldbank.org

World Health Organization:
www.who.int

World Resources Institute, Climate Analysis Indicators Tool:
www.cait.wri.org

World Tourism Organization's Compendium of Tourism Statistics
www.pub.unwto.org

Annex C: About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on environmental protection and sustainable development. In 2008, UNEP's new Medium Term Strategy (MTS) was adopted along six strategic priorities: climate change, disasters and conflicts, ecosystem management, environmental governance, harmful substances and hazardous waste, and resource efficiency. The selection of these six themes was guided by scientific evidence, the UNEP mandate, and priorities emerging from global and regional forums. UNEP's mandate has five main interrelated areas:

- Keeping the world environmental situation under review. UNEP provides access to environmental data notably through the Global Environment Outlook, which regularly assesses environmental change and its impact on people's security, health, well-being and development.
- Providing policy advice and early warning information, based upon sound science and assessments. UNEP has created several international scientific panels such as the Intergovernmental Panel on Climate Change, jointly established with the World Meteorological Organization in 1988 to assess the state of existing knowledge about climate change. The IPCC's reports helped raise awareness among the media and the general public about the human-made nature of climate change. UNEP also set up the International Panel for Sustainable Resource Management in 2007 and the Intergovernmental Platform on Biodiversity and Ecosystem Services in 2008. These complementary initiatives are aimed at providing policymakers with the science on which to base their decisions.
- Facilitating the development, implementation and evolution of norms and standards and developing coherent links between international environmental conventions. UNEP has helped establish and implement many international environmental agreements – such as the Montreal Protocol to restore the ozone layer, a growing number of treaties that governs the production, transportation, use, release and disposal of chemicals, and the family of treaties that protects global biodiversity.
- Catalyzing international co-operation and action and strengthening technology support and capacity in line with country needs and priorities. UNEP encourages decision-makers in governments, industries and businesses to develop and adopt environmentally sound policies, strategies, practices and technologies. This involves raising awareness, building international consensus, developing codes of practice and economic instruments, strengthening capabilities, exchanging information and initiating demonstration projects.

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- Raising awareness and promoting public participation. UNEP publications and outreach activities help disseminate scientific information to decision-makers and provide them with policy guidance. Moreover, special public events like the World Environment Day (every 5 June) or the Billion Tree Campaign stimulate worldwide awareness of environmental issues, encourage political action and promote behavioural change.

The Division works to promote:

- Sustainable consumption and production.
- Efficient use of renewable energy.
- Adequate management of chemicals.
- The integration of environmental costs in development policies.

The Office of the Director, located in Paris, co-ordinates activities through:

- The International Environmental Technology Centre – IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- Production and Consumption (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- Chemicals (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- Energy (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

Set up in 1975, three years after UNEP was created, the Division of Technology, Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: climate change, harmful substances and hazardous waste, resource efficiency.

DTIE is also actively contributing to the Green Economy Initiative launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

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MCA4climate is a major new UNEP initiative providing practical assistance to governments in preparing their climate change mitigation and adaptation plans and strategies. It aims to help governments, particularly in developing countries, identify policies and measures that are low cost, environmentally effective and consistent with national development goals. It does this by providing a structured approach to assessing and prioritizing climate-policy options, while taking into consideration associated social, economic, environmental and institutional costs and benefits. In doing so, it seeks to counter the widely held perception that tackling climate change is costly, highlight the potential developmental benefits of addressing climate change and encourage action to that end.

United Nations Environment Programme

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