ECONOMIC ANALYSIS OF CLIMATE-PROOFING INVESTMENT PROJECTS

ASIAN DEVELOPMENT BANK

ECONOMIC ANALYSIS OF CLIMATE-PROOFING INVESTMENT PROJECTS

ASIAN DEVELOPMENT BANK

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 632 4444; Fax +63 2 636 2444
www.adb.org; openaccess.adb.org

Printed in the Philippines.

ISBN 978-92-9257-077-4 (Print), 978-92-9257-078-1 (e-ISBN)
Publication Stock No. RPT157588-2

Cataloging-In-Publication Data

Asian Development Bank.
Economic analysis of climate proofing investment projects
Mandaluyong City, Philippines: Asian Development Bank, 2015.

1. Climate change 2. Risk management 3. Adaptation I. Asian Development Bank.

Note: In this publication, "$" refers to US dollars.

Contents

Tables, Figures, and Boxes

TABLES

FIGURES

BOXES

Abbreviations

ADB	Asian Development Bank
BCR	benefit-cost ratio
CP	climate proofing
CRVA	climate risk and vulnerability assessment
DMC	developing member country
EIRR	economic internal rate of return
GCM	general circulation model
IPCC	Intergovernmental Panel on Climate Change
NPV	net present value
UNFCCC	United Nations Framework Convention on Climate Change

Foreword

Climate change is a central challenge to development in Asia and the Pacific. Its impacts are already being felt. Sea levels are rising, glaciers are melting, temperatures are increasing, and rain patterns are changing, threatening the water, food, and health security of the region. Numerous countries of the region are among the most vulnerable to the adverse impacts of climate change globally, with poor and marginalized communities likely to be the most severely impacted.

Adjusting to the need for climate-resilient development will mean integrating responses to the physical, social, and economic impacts of climate change into all aspects of development planning and investment. The long-term strategic framework of the Asian Development Bank (ADB), Strategy 2020, and its climate change strategy, Addressing Climate Change in Asia and the Pacific: Priorities for Action, confirm ADB's commitment to support developing member countries in Asia and the Pacific in addressing the increasing challenges posed by climate change and to build a climate-resilient region. As ADB continues to support significant infrastructure investments in the region, ADB also seeks to enhance the climate resilience of vulnerable sectors by "climate proofing" investments and ensure intended development outcomes are not compromised by ongoing and projected climate change.

The complexity and uncertainty of the factors that define climate risks and vulnerability, particularly at a project scale makes climate proofing a challenging activity for scientists, engineers, economists and decision makers. ADB is developing a set of technical resources to assist both its own operational staff and developing member countries in managing climate-related risks and vulnerability throughout the project cycle. This set encompasses climate risk screening tools, technical guidelines for climate proofing investments in critical development sectors (e.g., transport, agriculture, and energy), and knowledge products capturing our experiences with climate proofing investment projects. These resources reflect ADB's as well as development partners' growing experience in using a wide range of approaches, methods, and tools aimed at increasing climate resilience in the region. It is hoped that these resources will also be of support and of interest to a much wider community of individuals and organizations addressing climate change risks.

This report aims to clarify how the economic analysis of climate-proofing measures can inform the design of investments. An important message of this report is that the principles guiding the economic analysis of climate proofing investment projects do not fundamentally differ from the principles guiding the economic analysis of any other investment project. However, decision-making processes need to account for the uncertainty associated with climate change. We hope that the report improves—and simplifies—the work of development professionals in their efforts to enhance the climate resilience of investment projects.

This report was prepared by Benoit Laplante (consultant) under the Technical Assistance for Enabling Climate Change Responses in Asia and the Pacific, financed by the ADB Technical Assistance Fund. Cinzia Losenno, senior environment specialist (climate change adaptation), Sustainable Development and Climate Change Department, provided technical and overall guidance in the finalization of the report. Loreta Rufo, senior climate change officer, Sustainable Development and Climate Change Department, provided overall assistance.

Valuable comments and suggestions were received from ADB's Environment Thematic Group and the Adaptation and Land Use Working Group. We particularly wish to thank the Economic Research and Regional Cooperation Department for their contribution and constructive comments on previous drafts of this report. The report also benefited from extensive discussion with Charles Rodgers (consultant). Sincere appreciation to Nessim Ahmad who initiated the report and provided overall guidance and support.

Ma. Carmela D. Locsin
Director General
Sustainable Development and Climate Change Department

Executive Summary

Given that the world is committed already to significant changes in climate conditions (as a result of historical greenhouse gas emissions), assessing the possible impacts of climate change on investment projects as well as assessing the technical and economic feasibility of a range of climate-proofing options has become a priority.

Recent years have witnessed a large number of studies and reports aimed generally at providing estimates of the economic costs of climate change and of the economic costs of adaptation to climate change. However, less attention has been devoted to the role and conduct of economic analysis in guiding climate-proofing decisions at the level of investment projects.

This report aims to describe the conduct of the cost–benefit analysis of climate proofing investment projects. It should not be understood as a substitute but as a complement to ADB's *Guidelines for the Economic Analysis of Projects* (ADB 1997) with the objective of highlighting the application of the guidelines to the economic analysis of climate proofing investment projects.

ADB's climate risk management framework aims to reduce risks resulting from climate change to investment projects in Asia and the Pacific. A key step in this framework is the technical and economic evaluation of climate-proofing measures.

The basic purpose of undertaking the cost–benefit analysis of an investment project is to provide information to decision makers as to the contribution of the project to society's welfare. The analysis provides a means to systematically identify, quantify, and wherever possible value all impacts of the project, including (where relevant) its environmental impacts, even in circumstances when these impacts occur over long time horizons.

The role of the economic analysis is to support decision making as it provides information pertaining to the economic efficiency of investment projects, including the economic efficiency of climate proofing investment projects. The economic analysis is not a substitute but an input to decision making.

The economic analysis of climate proofing an investment project can help address questions of the following nature:

- What are the impacts of projected climate change on the costs and benefits of the investment project?

- Is climate proofing the investment project desirable or should the project proceed without climate proofing?
- If there are multiple technically feasible and economically desirable climate-proofing measures, which of these should be recommended?
- Should cobenefits associated with some climate-proofing measures, such as ecosystem-based approaches, be included in the economic analysis?
- If climate proofing is desirable, when is the best time to undertake such investment over the course of the lifetime of the project?
- Should climate proofing be postponed until better information becomes available and allows the use of actual and observed climate conditions instead of uncertain climate projections?

While it is duly noted that there remains considerable and perhaps irreducible uncertainty pertaining to climate change projections, the presence of uncertainty about climate change does not invalidate the conduct of the economic analysis of an investment project and climate-proofing measures, nor does it require a new type of economic analysis. While better and more accurate information may be desirable (ignoring the cost of producing such information), the economic analysis of investment projects and of their climate proofing does not demand accuracy and precision from climate projections.

The principles guiding the economic analysis of climate proofing investment projects do not differ from those guiding the analysis of any other investment project. However, the presence of uncertainty does require a different type of decision-making process in which technical and economic expertise combine to present decision makers with the best possible information on the economic efficiency of investment projects in the context of a changing climate and of investments in climate-proofing options.

The outcome of the economic analysis of climate-proofing options may result in three different types of decisions: (i) climate proof now; (ii) make the project climate-ready; or (iii) wait, collect information and data, and revise if needed.

Decision makers may elect to invest in climate-proofing measure(s) at the time the project is being designed (climate proof now) under circumstances where any of the following applies:

- The costs of climate proofing now are estimated to be relatively small while the benefits (the avoided expected costs from not climate proofing), even though realized only under future climate change, are estimated to be very large. This is occasionally referred as a *low-regret* approach.
- The costs of climate proofing at a later point in time are expected to be prohibitive or climate proofing later is technically not possible.
- Among the set of climate-proofing options, one or more options deliver net positive economic benefits regardless of the nature and extent of climate change. Such options are occasionally referred as *no-regret* climate-proofing options.
- The set of climate-proofing options includes at least one option that not only reduces climate risks to the project, but also has other social, environmental, or economic benefits (cobenefits). Such options are occasionally referred as *win-win* climate-proofing options.

Alternatively, decision makers may elect to invest minimally at the time of project design and implementation to ensure that the project can be climate proofed in the future if and when circumstances indicate this to be a better option than not climate proofing. This type of decision aims to ensure that the project is "ready" for climate proofing if and when required. As such, the concept of climate readiness is occasionally referred to in this situation. This concept is akin to the real option approach to risk management. It involves avoiding the foreclosure of climate-proofing options and preserving flexibility to improve climate resilience as climate change is actually observed (as opposed to projected).

For example, while current sea level rise and storm surge scenarios may not warrant the construction today of sea dikes suitable to projected higher sea level and stronger storm surges in a distant future, the base of the sea dike may nonetheless be built large enough at the time of construction to accommodate a heightening of the sea dike at a later point in time.

Finally, decision makers may elect to make no changes or incremental investment at the time of project design and implementation, but instead to await further information on climate changes and their impacts on the infrastructure assets, and to invest in climate proofing if and when needed at a later point in time.

This type of decision may result under one or more of the following circumstances:

- The costs of climate proofing now are estimated to be large relative to the expected benefits.
- The costs (in present value terms) of climate proofing (e.g., retrofitting) at a later time are expected to be no larger (or little different) than climate-proofing now.
- The expected benefits of climate proofing today are estimated to be relatively small.

The last two types of decisions are akin to an adaptive management approach, which consists of monitoring changes in climate and putting in place climate-proofing measures over the project's lifetime as changes and their impacts are observed. Key to both types of decisions is to ensure that appropriate data and information are collected.

The process of climate proofing investment projects aims both at assessing the climate risk to a project's future costs and benefits and at undertaking a technical and economic analysis of options to alleviate or mitigate those risks. Accounting for climate change at the outset of the project cycle does not imply that climate-proofing measures with large and costly investments need to be put in place as project implementation is initiated. It does imply, however, that decisions about project design and the adoption and timing of climate-proofing measures be informed with the possible impacts of climate change in the initial phases of the project cycle and that decisions of an irreversible nature be avoided.

Introduction

A Commitment to Climate Change

Global and regional data show that the temperatures of land surface air and sea surface have both increased in the course of the last century. Records also show that maximum and minimum temperatures over land have increased since the mid–20th century, and that each of the past 3 decades has been warmer than any previous decade in recorded history (IPCC 2013). Similar trends have been observed in Asia and the Pacific. Reductions in the volume of glaciers and ice sheets combined with the thermal expansion of the oceans (among other factors) have led to a rise in global mean sea level.[1] Records show that the rate at which global mean sea level is rising has increased from 1.7 millimeters per year (mm/y) over the period 1901–2010 to approximately 3.2 mm/y over the period 1993–2010.

Looking into the future, the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013, IPCC 2014.) confirms many findings of earlier assessment reports: further increases in temperature, further rise in sea levels, and greater frequency and/or higher intensity of extreme weather events.[2] The report reassesses that near-term warming from past emissions is unavoidable: barring major volcanic eruptions and significant changes in solar irradiance, global mean surface temperature for the period 2016–2035 is likely to be 1.0 to 1.5 degrees Celsius (°C) above the average temperature observed over the period 1850–1900.[3] Mitigation actions, even if strong and immediate, do not produce different climate change outcomes for the next 30 years or so. Similarly, while there remains uncertainty as to the extent of sea level rise (the Fifth Assessment Report reports average sea level rise projections ranging from approximately 0.4 to 0.7 meters, with

---

1 Domingues et al. (2008) estimate that the thermal expansion of oceans has contributed to approximately 40% of observed sea level rise over the period 1961–2003, the melting of glaciers and ice caps has contributed 35%, and changes in the large polar ice sheets of Greenland and Antarctica have contributed approximately 25%. IPCC (2013) projects thermal expansion to be the single-largest contributor to sea level rise in the 21st century. However, as warming continues, melting and dynamic changes in the Greenland and Antarctic ice sheets are projected to become dominant contributors to sea level rise (Hanna et al. 2013, King et al. 2012, Nick et al. 2013, and Rignot et al. 2011).

2 It is generally expected that global warming may lead to fewer but more intense tropical cyclones (Knutson et al. 2010): as sea surface temperature rises, the potential intensity (the upper limit of wind speed) of cyclones increases. Recent evidence suggests that storms of maximum intensities have migrated toward the poles over the past 30 years at a rate of approximately 1 degree per decade (Kossin et al. 2014). This suggests that coastal communities that have historically not been exposed to tropical cyclone hazards may be facing increasing threats.

3 Important sources of uncertainty with respect to projected global mean temperatures pertain to the future role of land and oceans in acting as carbon sinks (Canadell et al. 2007), as well as the possible release of large quantities of carbon from thawing permafrost (DeConto et al. 2012, Schuur et al. 2013). Climate sensitivity—the estimated change in global equilibrium mean surface temperature as a response to changes in radiative forcing following a doubling of atmospheric concentration of carbon dioxide—remains a critical source of uncertainty when projecting future global temperatures (Rogelj et al. 2012, Rohling et al. 2012).

a maximum rise of 0.98 meters, by 2100), there remains no uncertainty as to the nature of the change: sea level will continue to rise for the forthcoming decades if not centuries (Levermann et al. 2013 and Meehl et al. 2012). This is generally referred to as the earth's commitment to climate change. Plattner et al. (2008) and Solomon et al. (2009) show that increases in atmospheric temperature resulting from existing increases of carbon dioxide concentration are largely irreversible up to 1,000 years after emissions stop. While a global temperature increase of 2°C has been defined as "dangerous anthropogenic interference" with climate systems, the likelihood of limiting global warming to less than 2°C is generally considered to be very small as it would require immediate and deep cuts in global emissions (UNFCCC 2009a).

Due to its vast and varied geography as well as being home to the largest populations of the poor and vulnerable, Asia and the Pacific is at high risk from climate change, and will experience significant climate-related impacts. IPCC's Fifth Assessment Report notes that climate change will

- reduce renewable surface water and groundwater resources, exacerbating competition for water among sectors above and beyond other direct human sources of pressure such as land use change, pollution, and inadequate practices of water resource management;
- increase the risk of submergence, coastal flooding, and coastal erosion in coastal systems and low-lying areas including those of the Pacific developing member countries (DMCs). By 2100, hundreds of millions of people on the region's coastlines alone are projected to be affected by climate change, with the majority of these affected people being in East, Southeast, and South Asia; and
- adversely impact human health by further exacerbating health problems associated with heat stress, extreme precipitation, flooding, drought, and water scarcity.

As a result, while mitigation must remain an important objective to avoid catastrophic climate change, there is currently significant empirical evidence supporting a strong emphasis on building climate risk resilience in Asia and the Pacific, which is not limited to but includes climate proofing ongoing and future infrastructure development projects. Discussions have gradually moved away from questioning the need to climate proof investment projects to increasingly asking: *how, how much, and when?*

Asian Development Bank Response

The long-term strategic goal of the Asian Development Bank (ADB) set out in Strategy 2020 (ADB 2008) emphasizes environmentally sustainable growth as a key pillar to achieving an Asia and Pacific region free of poverty, including adaptation to the unavoidable impacts of climate change. In particular, it commits ADB to supporting its DMCs in climate proofing investment projects.

In 2010, ADB defined its priorities for action to assist DMCs in addressing climate change. In particular, these priorities include assisting DMCs in climate-proofing projects to ensure their outcomes are not compromised by climate change and variability or by natural hazards in general (ADB 2010, p. 10). ADB's *Environment Operational Directions 2013–2020* (ADB 2013a) articulates the strategic agenda for pursuing environmentally sustainable growth and enhancing resilience to climate change. At the project level, it asserts ADB's commitment to help DMCs develop climate-proofed infrastructure and to embed climate proofing in the project cycle. ADB makes a clear and strong commitment in the midterm review of Strategy 2020 (ADB 2014a) to further mainstream climate risk management:

> ADB will further mainstream adaptation and climate resilience in development planning, as well as in project design and implementation. This will be pursued, for instance, through systematic screening of infrastructure projects to identify those at risk of being adversely affected by climate change, and by "climate-proofing" vulnerable projects to make them resilient to climate change impacts (ADB 2014a, p. 26)

In support of this overall objective to climate proof investment projects, ADB has recently institutionalized a climate risk and vulnerability assessment approach. The approach is a process that aims to screen all ADB investment projects for their exposure and vulnerability to climate risk. It is initiated with a climate risk screening, and leads to the undertaking of a detailed climate risk and vulnerability assessment if the screening process reveals the project to be at medium or high climate vulnerability.

ADB has continued to develop and pilot test methods and tools to assess climate change vulnerability and impacts, and to identify adaptation[4] needs and options. These methods and tools aim to assist ADB and DMCs in managing climate change risks throughout the project cycle. They include sector briefings on adaptation, as well as technical notes that provide guidance for the assessment of climate impacts, evaluation of risks, identification and prioritization of adaptation options, and monitoring and evaluation of adaptation measures.

As with any other investment project, climate proofing investments involves trading off the cost of such investment against future (and uncertain) benefits. The economic analysis of such investment aims to provide guidance to project stakeholders and decision makers on answering the *how, how much, and when* of climate proofing investment projects. This report aims to provide guidance on the undertaking of the economic analysis of climate proofing investment projects.

Scope of the Report

Recent years have witnessed a large number of studies and reports aimed generally at providing estimates of the economic costs of climate change and of the economic costs of adaptation to climate change.

At the global and regional levels, Stern (2007), Nordhaus (2008), and Tol (2002), among numerous others, have provided estimates of the *economic impacts (costs) of climate change*, generally presented in absolute terms or as a percentage of projected gross domestic product (GDP).[5] ADB (2009) has estimated that the cost of climate change in Indonesia, the Philippines, Thailand, and Viet Nam could equal a loss of nearly 7% of their combined

---

4 Please note that in this report, "adaptation" and "climate proofing" are used interchangeably for convenience of presentation.

5 See Tol (2009) and Springmann (2012) for a review of studies of a similar nature.

gross domestic product by 2100. For the South Asia region, ADB (2014b) estimated that the region could lose nearly 2% of its GDP by 2050, rising to a loss of nearly 9% by 2100 under a business-as-usual scenario—higher still if losses due to extreme weather events are added. At the sector level, a number of studies have focused on the economic costs of the effects of climate change on agriculture.[6]

Other studies have aimed to assess the *costs of adaptation* to climate change, generally presented as the investment necessary to restore an estimated baseline reference of development. Annual adaptation costs have been estimated to reach approximately $40 billion in Asia and the Pacific over the period 2010–2050. For the Pacific region alone, ADB (2013b) estimated that the region would require $447 million on average every year until 2050 (approximately 1.5% of GDP) to prepare for a worst-case climate change under the business-as-usual scenario. The cost could be as high as $775 million or 2.5% of GDP per annum. A World Bank report on the economics of climate change adaptation (World Bank 2010a) is an influential example of such studies at the global level, with estimates of the global cost of adaptation ranging from $70 to 100 billion up to 2050 (in 2005 prices).[7] A study by Westphal et al. (2013) is another example of such analysis at the regional level. Parry et al. (2009) have noted that the vast discrepancy in methods as well as in geographic and sector coverage across the existing set of analyses have resulted in a large range of estimates of the economic costs of climate change and of adaptation.

Less attention has been devoted to the role and conduct of economic analysis in guiding climate-proofing decisions at the level of investment projects. Yet, with the mounting evidence that significant climate change cannot be avoided over the course of the coming decades, it has become increasingly recognized that investment projects (especially those involving infrastructure with long-term horizons) would benefit from a greater understanding and accounting of (i) the exposure and vulnerability of the infrastructure assets to climate change impacts, and (ii) the means and options to reduce the projected impacts of climate change on these assets.

This report aims to describe the conduct of the cost–benefit analysis of climate proofing investment projects. Given this focus, it is important to note what this report does not aim to do.

This report is neither a review of nor an additional economic assessment of the global, regional, local, or sectoral cost of climate change or cost of adaptation to climate change. Furthermore, this report is not a review of the existing conduct and practice of cost–benefit analysis of investment projects. Finally and importantly, this report does not aim to be a substitute for ADB's *Guidelines for the Economic Analysis of Projects* (ADB 1997). The concepts, techniques, and criteria set out in those guidelines (and in any of its updates) remain the basis for the conduct of all economic analyses of investment projects and for the evaluation of such analyses. This report aims to be a supplementary reference to the ADB's *Guidelines for the Economic Analysis of Projects* with the objective of highlighting the application of these concepts, techniques, and criteria to the economic analysis of climate proofing investment projects.

[6] See ADB (2012a) for a review of such studies.
[7] Other studies include Oxfam International (2007), UNFCCC (2009b), and Parry et al. (2009).

Defining "Climate Proofing"

In this report, the expression "climate proofing" is meant as (i) a process that aims to identify risks that an investment project may face as a result of climate change, and to reduce those risks to levels considered to be acceptable, and (ii) a measure aimed at mitigating the climate risk to which a project is exposed.

In the first instance, the expression is used in a way similar to the meaning provided in ADB (2005):

> Climate proofing is a shorthand term for identifying risks to a development project, or any other specified natural or human asset, as a consequence of climate variability and change, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable, and socially acceptable changes implemented at one or more of the following stages in the project cycle: planning, design, construction, operation, and decommissioning" (p. xii).

In this context, the expression "climate proofing" thus generally refers to a process, *not* to an outcome.

On the other hand, in a number of circumstances, the expression can also refer to a specific measure or option intended to reduce or offset the impacts of climate change on the costs and/or benefits of an investment project. The specific context in which the expression is used should indicate which of these two meanings is intended.

However, it is of importance to note that the expression "climate proofing" does not imply a complete mitigation of the potential risks of climate change. In most circumstances, an economically efficient response to climate risk will leave some impacts unmitigated even with the implementation of climate-proofing measures (the concept of residual damages is discussed further below).

Target Audience

The writing of this report has been guided by the nature of the target audience, which consists mostly of the following two groups.

A first target audience consists of policy makers who—upon understanding the nature of risks posed by climate change—have the authority to make decisions as to whether society's scarce resources shall be allocated to increase the climate resilience of investment projects. The answer to "how, how much, and when" ultimately belongs to decision makers of the borrowing countries. The economic analysis of climate-proofing options aims to be a guide in this decision-making process.

A second target audience comprises ADB project teams, including economists among project teams, who are now requested to account for the possible impacts of climate change on investment projects. ADB has developed a set of tools and materials, including this paper, to support this process.

It is with these groups of readers in mind that trade-offs were made as to the appropriate coverage of topics and level of technicality to include in the report.

Structure of the Report

The methodological approach to conducting the economic analysis of climate proofing investments is presented in Part A. Part A discusses the role of the economic analysis, and provides more details on the identification of the (physical) impacts of climate. Part B provides a detailed description of the conduct of the economic analysis of climate proofing investment projects. Part B (i) clarifies the important difference between the costs of climate change and the benefits of adaptation, (ii) discusses the inclusion of cobenefits (or ancillary benefits) in the economic analysis of climate-proofing measures, (iii) discusses the selection of discount rate in the economic analysis of climate proofing investments, and (iv) concludes with the use of decision rule in economic analysis. Part C focuses more specifically on approaches aimed at handling uncertainty in the economic analysis of climate proofing investments. Final remarks and recommendations are presented in the conclusion.

An important message of this report is that the principles guiding the economic analysis of climate proofing investment projects do not differ from those guiding the analysis of any other investment project.[8] The presence of uncertainty pertaining to climate projections does not invalidate the conduct of economic analysis, but instead calls for a renewed interest in the conduct of economic analysis in support of decision making.

[8] Chambwera and Stage (2010) write, "The standard toolbox used in cost/benefit analysis is still useful for assessing adaptation measures, provided that the correct baseline is used."

PART A Setting the Stage: The Role of Economic Analysis and the Impacts of Climate Change

The Role of Economic Analysis

What Economic Analysis Is

In its broadest sense, a cost–benefit analysis is a process of assessing the pros and cons of an investment project or policy. When undertaken from the point of view of the owner of the project operating entity (which may be public and/or private), the financial (cost–benefit) analysis aims to assess the overall impact of the project on the owner's wealth (or fiscal resources when the owner is a public entity); when undertaken from society's point of view, the economic (cost–benefit) analysis aims to assess the overall impact of the project on society's well-being or welfare.

These different, albeit not necessarily divergent, points of view explain a number of key differences between the two types of analysis, including adjustments made to market prices to account for the *social or economic* (as opposed to private) costs and benefits of a project's inputs and outputs (a process referred to as shadow pricing), and the economic valuation of a project's environmental impacts. For the purpose of this report, the discussion will pertain to the economic analysis of investment projects, and unless otherwise indicated, the expression *cost–benefit* analysis and economic analysis will be used interchangeably.

The basic purpose of undertaking the economic analysis of an investment project is to provide information to decision makers as to the expected contribution of the project to society's welfare.[9] The analysis provides a means to identify, quantify, and wherever possible value all impacts of the project, including (where relevant) its environmental impacts. An economic analysis thus serves as a framework to organize and assess in quantitative (dollar) terms the pros and cons of an investment project in a systematic and structured manner. The sole aim and focus of the economic analysis is to ensure the best possible use and allocation of society's limited resources, a concept referred to as economic *efficiency*.[10]

With respect to climate proofing investment projects, the economic analysis plays an identical role. The economic analysis of the potential impacts of climate change and of investing in climate-proofing measures aims to identify, quantify, and value both the

9 In ADB (2013c), one reads, "Economic analysis helps assess sustainability of investment projects that will improve the welfare of the beneficiaries and a country as a whole."

10 Hallegatte (2014) refers to cost–benefit analysis (CBA) as follows: "CBA can be used to collect information on the consequence of a project, and to help organize the debate, by linking different opinions of various groups on what should be done to different opinions about the parameters of the analysis. CBA should therefore be understood as a complement and a tool to open consultations and discussions, not as a replacement for them." (p. 172)

possible impacts of climate change on the costs and benefits of the project, and the possible measures that could potentially mitigate these impacts. The outcome of the analysis will reveal whether (from an *economic efficiency* point of view) climate proofing should be implemented, and—in circumstances where multiple technically feasible climate-proofing options are available—which climate-proofing option should be recommended to decision makers. Where relevant, the economic analysis can also indicate the best timing of such climate-proofing investments.

Numerous governments and institutions have developed guidelines for the economic analysis of investment projects.[11] A project's economic analysis is implemented via a number of steps. In the context of ADB-funded projects, these steps are highlighted in ADB's *Guidelines for the Economic Analysis of Projects* and in section G1/BP of ADB's *Operations Manual*.

The identification and quantification of the potential impacts of the project are important steps of the analysis. It requires assessing how a future world (within the selected geographical scope of analysis) is likely to change in the absence of the project (*scenario without project*), and to compare this hypothetical construction with another hypothetical construction in which the project is taking place (*scenario with project*). Such impact identification and quantification typically requires expertise well beyond economics.

Given that one looks into a possible future with and without the project, the process of impact identification and quantification is by definition fraught with uncertainty and requires a large number of assumptions as to what *may* happen in two future unknown worlds, one with the project and one without it. While climate change may introduce a new (arguably peculiar) form of uncertainty to a project's economic analysis, uncertainty is not new to the economic analysis. *All* economic analyses have *always* been conducted in a context of uncertainty (at best), and many with incomplete or unreliable information (at worst). The construction of scenarios, whether they pertain to climate change or not, has always been and will always be needed, and their validity can only be known if and when ex post analyses are performed.

In the context of climate proofing investment projects, the economic analysis aims to answer the following important questions:

- How will projected climate change impact the estimated costs and benefits of the investment project? If there were to be no technically feasible measure to mitigate these impacts, would the project still be economically viable?
- Is climate proofing the investment project desirable[12] from an economic efficiency point of view? If yes, should climate proofing take place at the time of project implementation (built into project design), or should it be delayed to a later point in time? What is the "best timing" to climate proof the investment?
- Should benefits other than those strictly associated with climate proofing the investment project be included in the economic analysis?

[11] See, for example, ADB (1997), Commonwealth of Australia (2006), European Commission (2008), H.M. Treasury (2003), Treasury Board of Canada (2007), and World Bank (1992). Textbooks include Boardman et al. (2010).

[12] The meaning of the word "desirable" will be discussed in Part B.

- If there are multiple technically feasible and economically desirable climate-proofing options, which of them should be recommended?

What Economic Analysis Is Not

Despite the recent criticized practice of economic analysis of investment projects (Box 1), the economic analysis can play an important role in *guiding* decision making pertaining to climate proofing investment projects.

It is important to recognize that a project's economic analysis has a number of important limitations, two of which are of particular interest in the context of this report.

First, a project's economic analysis does not and cannot provide estimates of a project's costs and benefits and of the resulting net present value with absolute certainty. It can only provide a possible range of a project's net present value within which the true (and unknown) net present value *may* fall within a reasonable degree of confidence. Absolute certainty is beyond the realm of any economic analysis.

Second, as indicated earlier, the economic analysis aims to provide information on the *economic efficiency* of an investment project. It does not provide information as to the political feasibility, legality, or social and cultural acceptability of the project. Furthermore, while distributional (equity) issues may be addressed by assigning distributional weights to the costs and benefits as they accrue to different social or income groups, a general practice is to leave such issues to the political process and to assume that the economic value of a dollar of cost or benefit is the same regardless of where it accrues. However, it remains good practice for an economic analysis to identify the distribution of costs and benefits across stakeholders so as to inform decision makers as to the distributional impacts of the project. ADB requires the conduct of such distributional analysis.[13] This strongly indicates that the outcome of the economic analysis should not be—and in fact is typically not (as implicitly suggested in Box 1)—the only criterion used in assessing the social desirability of an investment project.

As indicated above, a necessary starting point of the economic analysis of climate-proofing options is to assess the nature and possible extent of the potential impacts of climate change on the project's performance.

---

[13] Section G1/OP of ADB's *Operations Manual* (ADB 2003) requires the conduct of distributional analysis: "Project beneficiary and stakeholder groups, and the extent to which they gain from benefits or bear costs associated with a project, should be identified. Where project effects are intended to benefit a particular target group, the proportion on net benefits going to that group should be assessed."

Box 1: On the Use of Economic Analysis in World Bank Projects

In a recent review of the conduct of cost–benefit analysis of World Bank investment projects, the Independent Evaluation Group of the World Bank found the practice of cost–benefit analysis to be seriously lacking. Findings of interest include the following:

- The weak points in economic analysis of bank projects are fundamental issues such as public sector rationale, comparison against alternatives, and measurement of benefits against a without-project counterfactual.
- Cost–benefit analysis is conducted after the decision to go ahead with the project has been made, which puts the analysis under considerable pressure to reach conclusions consistent with the decisions already taken.
- Staff appraisal reports fail to convey the possible range of rates of return, and downside risks are systematically ignored.
- Staff appraisal reports typically present a single alternative—that of the project chosen. There is little evidence that a systematic effort to compare and choose from among alternatives is a major part of decision making.
- Risk analysis emerges as one of the weakest areas. The typical analysis of risk consists of sensitivity analysis by simply varying aggregate costs and benefits by some percentage. Fewer than 10% of the projects perform Monte Carlo analysis.

Source: World Bank. 2010. *Cost–Benefit Analysis in World Bank Projects*. Independent Evaluation Group. Washington, DC: World Bank

Conducting a Climate Risk and Vulnerability Assessment of Investment Projects

ADB continues to develop and pilot test methods and tools to assess climate change impacts and vulnerability, and to identify adaptation needs and options. These methods and tools aim to assist ADB and developing member countries in managing climate change risks throughout the project cycle. They include (i) risk screening tools that enable rapid risk assessment at the project preparation stage; (ii) sector briefings on adaptation; and (iii) technical guidelines for the assessment of climate impacts, evaluation of risks, identification and prioritization of adaptation options, and monitoring and evaluation of adaptation measures. ADB's approach to climate risk management has evolved from an initial identification of entry points for promoting adaptation in operations to a more rigorous framework to systematically identify proposed investments that may be adversely affected by climate change at the very early stages of project development and incorporate risk reduction measures in the project design.

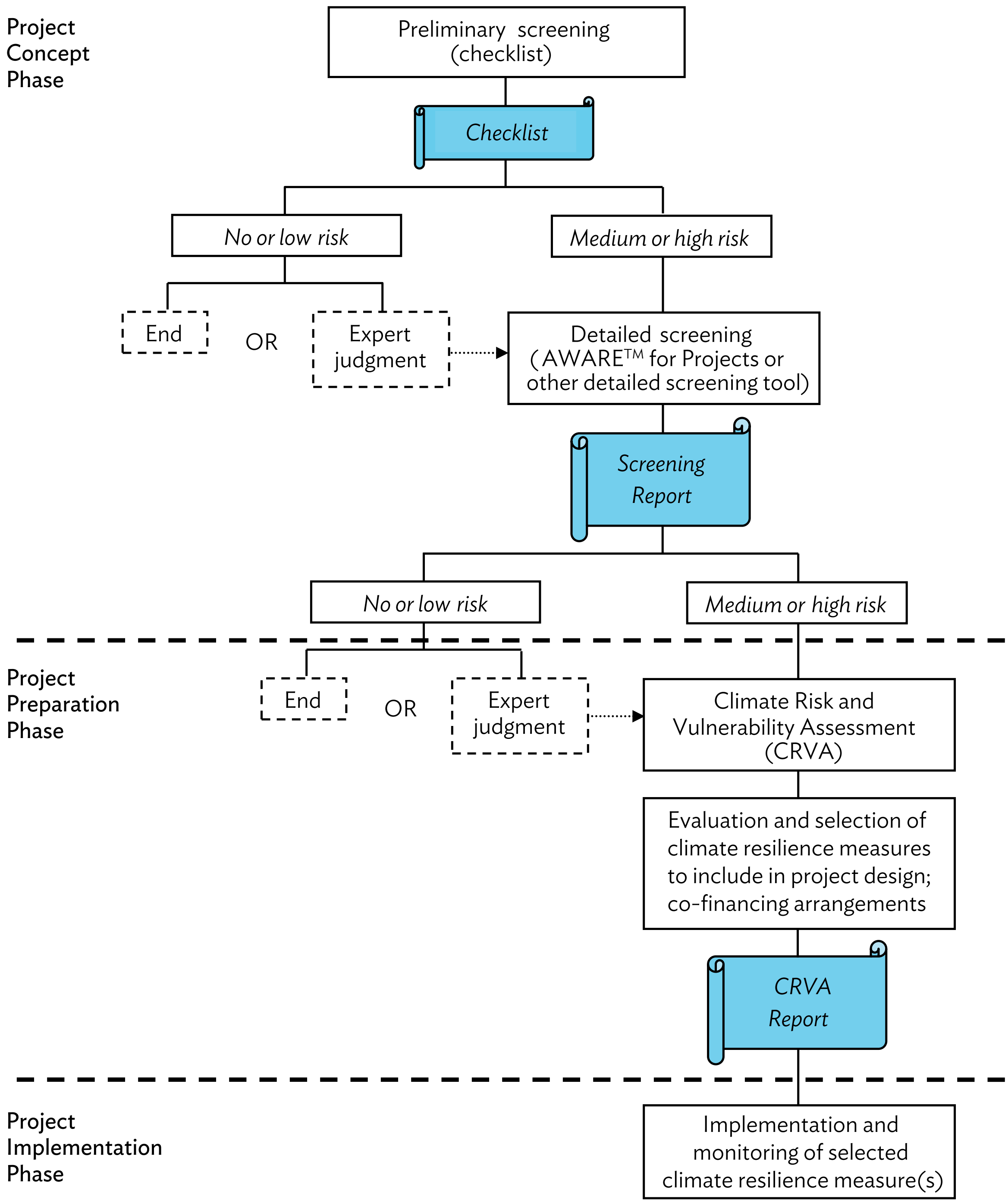
This framework (Figure 1) was institutionalized in early 2014 as a response to the mandated requirement that exposure and vulnerability to climate change risks be identified and accounted for in the preparation of investment projects. The basic stages of the framework are as follows:

- ***Stage 1:*** A preliminary climate risk screening to identify projects that may be at risk. This first stage, undertaken at the project concept stage by the project processing team, is embedded in the project's rapid environmental assessment. This first step aims to provide an initial assessment of the level of sensitivity of the project location and project components to climate variables such as temperature, and rainfall quantity and temporal distribution. This preliminary risk screening, reported in project documents, will indicate whether further climate risk screening should be undertaken.
- ***Stage 2:*** A detailed risk screening of projects that are considered at medium or high risk. This second stage is also implemented by the project team at the project concept stage. While still a screening mechanism, this step aims to detail the specific nature of the climate risks. To support this process, ADB has developed climate risk management tools and materials for use at the sector and project levels. A rapid risk assessment tool, AWARE™ for Projects, is available to project teams to promote a more harmonized approach to climate risk screening. Operational departments may also apply approaches that suit their needs in conjunction with the in-house knowledge and expertise. As for the preliminary risk screening, the outcome of the detailed risk screening is reported in project documents. A risk rating of *medium* or *high* should then lead to the undertaking of the third assessment.

Stage 1 and Stage 2 are components of the climate risk screening process to be implemented at the project concept phase.

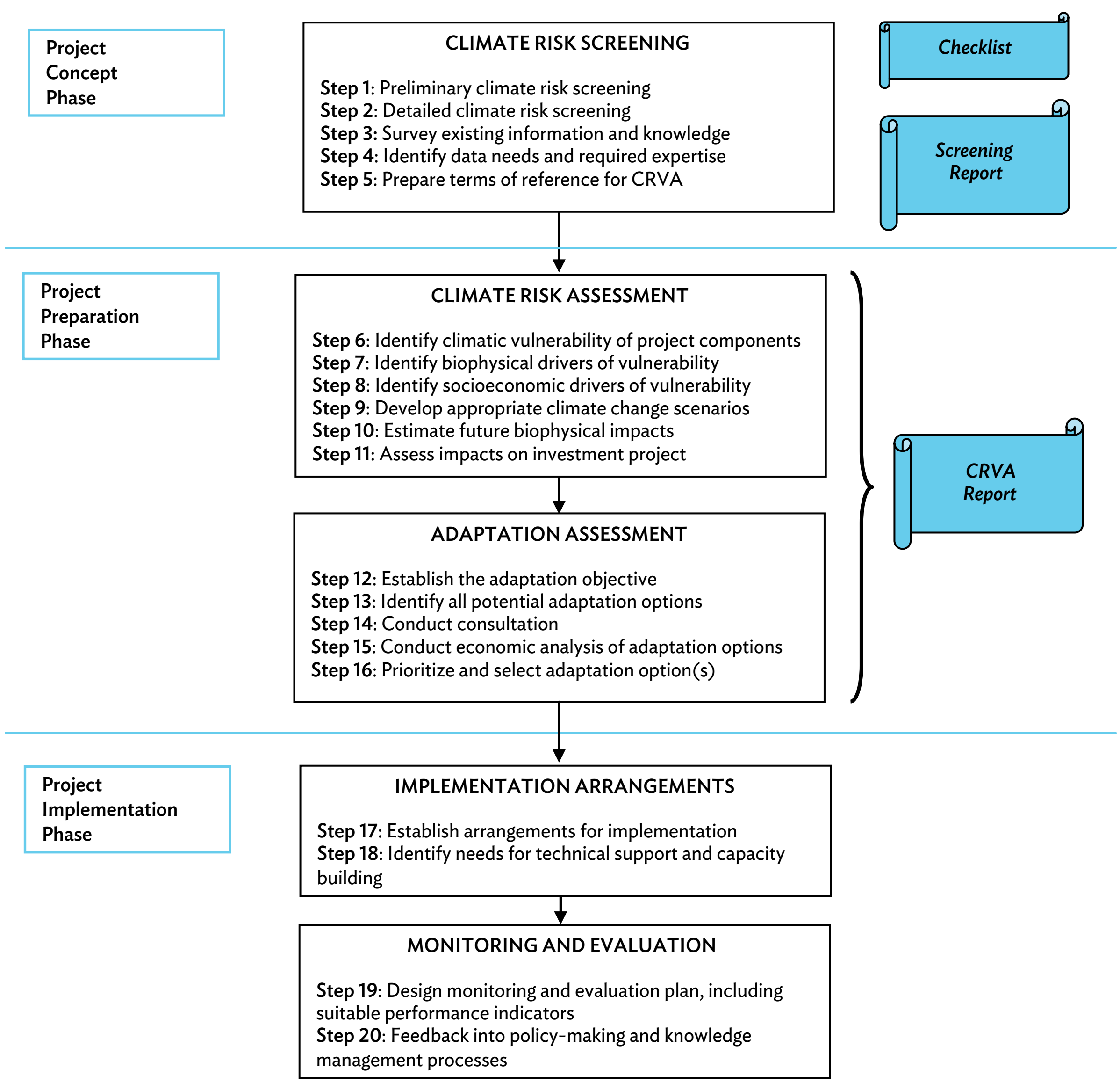
- ***Stage 3:*** A climate risk and vulnerability assessment (CRVA), which aims to assess climate change risks to the project and to incorporate adaptation measures in the project design. This stage, undertaken during project preparation phase, typically requires analysis of climate data (including climate model projections and projections of sea level rise as appropriate); impact assessments on project infrastructure, inputs, and performance; and technical and economic feasibility analyses of adaptation options. It is in the context of conducting a CRVA in the course of the project preparation phase that the economic analysis of the impacts of climate change and of adaptation options described in this report applies. The CRVA should be available among the set of project documents.
- ***Stage 4:*** Reporting of the climate risk screening and vulnerability assessment. The level of risk identified during concept development and the findings of the CRVA carried out during project preparation are documented in the report and recommendations to the President and other ADB board documents. A supplementary document describing the CRVA, the adaptation measures incorporated in the project design, and associated costs can also be linked to the ADB board documents. The level of risk assigned to the project is recorded in the ADB project classification system for monitoring and reporting purposes.

Figure 1: Flowchart for Assessing Climate Risk of Projects



The framework presented in Figure 1 is usually divided into a set of steps aligned with the ADB project cycle (Figure 2). In a recent review of CRVA conducted for 11 investment projects in the transport sector (ADB 2014c), weaknesses in the conduct (or lack thereof) of the economic analysis of climate proofing investment projects were highlighted. This justifies the focus of this report on the conduct of the economic analysis of climate proofing investment projects (Step 15).

Figure 2: Steps for Climate Risk Management of Investment Projects



It is important to note that issues pertaining to climate modeling (including the selection of climate models and their downscaling), and then to assessing the impacts of projected changes in climate variable(s) on project performance (which may, in relevant circumstances, include hydrological modeling), are key components of a CRVA (Steps 6 to 11 in Figure 2), and will serve as input to the economic analysis of climate-proofing options. However, this assessment of the climate risk and impacts (Box 2) requires expertise other than that offered by the economist. While this report focuses on the economic analysis, the following points are worth highlighting:

- While climate change challenges conventional assumptions about the stationarity of climate conditions,[14] this does not imply that the use of historical meteorological data must be avoided. In fact, in many circumstances, climate proofing investments to observed climate variability is likely to be an appropriate step toward ensuring the climate resilience of these investments (Lopez et al. 2011).
- It is important to understand that climate projections are not forecasts or predictions, but provide plausible alternative characterizations of future climate conditions. Climate change scenarios should not be interpreted as representing the most likely future values of the climate variables of interest (e.g., precipitation, temperature, or sea level rise). As such, for the purpose of adaptation planning, it is generally inappropriate to estimate and use average (mean) projection across climate models.[15] It is more useful to establish plausible lower and upper bounds of climate change to allow testing for the possible impact of climate change on the project's costs and benefits across numerous scenarios.[16]

As noted in ECA (2009),

> … it is important to remember that a climate risk assessment exercise is not predictive in nature, but rather designed to understand the range of possible outcomes to help incorporate future climate risk into decisions today. Building scenarios based on existing science and being explicit about the range of uncertainty is critical: such scenarios allow potential future climate-related loss [and thereby potential benefits of climate proofing—this bracket ours] to be quantified (page 65).

[14] As indicated in Milly et al. (2008), stationarity "implies that any variable (e.g., annual stream flow or annual flood peak) has a time-invariant probability density function whose properties can be estimated from the instrument record. Under stationarity, future variability in climate conditions is assumed to be identical to observed historical variability."

[15] For example, it is possible to imagine a situation where a subset of climate models predict a significant decrease in rainfall, and another subset of models project a significant increase in rainfall, yielding "on average" a projected 0% change in precipitation across all projections, which may greatly understate the risks implied in various individual projections.

[16] Readers interested in more details on the above issues may refer to ADB's technical guidelines (ADB 2011a, 2012a, 2013d) as well as numerous publications on the nature and use of climate change projections, including IPCC (2014).

Box 2: Climate Change Vulnerability Assessment: A Combined Cycle Power Plant in Viet Nam

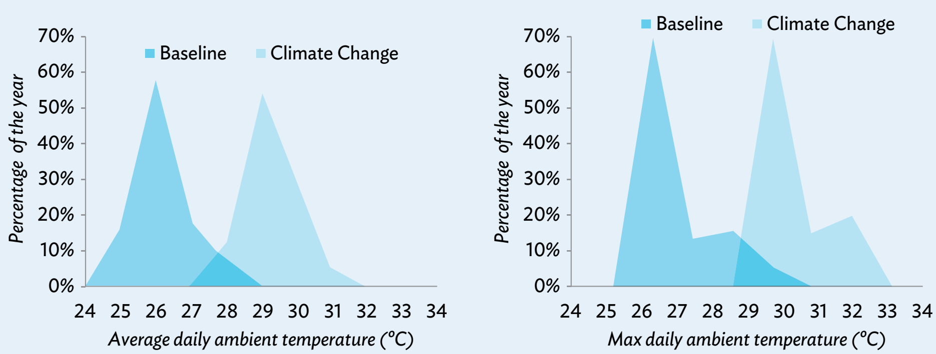
Climate change may have significant impacts on the generation of electricity, including from thermal power plants. Higher air temperatures may reduce the power generation efficiency of thermal power plants, leading to a reduction of power generation. Furthermore, an increase in water temperature may adversely impact the operation of the cooling systems of thermal power plants.

O MON IV is a proposed combined cycle gas turbine thermal power station in southern Viet Nam with a design capacity of 750 megawatts. It is designed for an ambient air temperature of 30°C, which is on average 3.3°C above the long-term historical annual average.

The O MON IV rapid climate change risk and vulnerability study addressed three questions related to plant operations and assets: (i) What are the direct biophysical climate change threats the plant is exposed to? (ii) What are the projected magnitude and duration of this exposure? (iii) Which operational, management, and infrastructure components of plant design are sensitive to climate change?

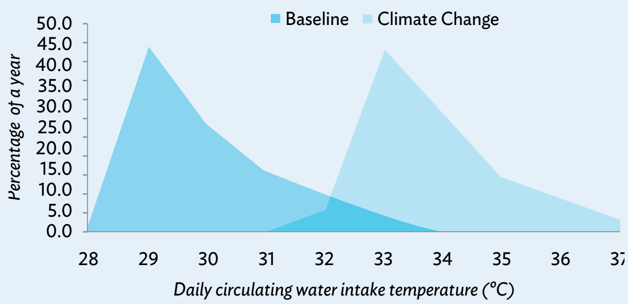
Approach to vulnerability analysis. To explore the climate change impacts on the plant, the results from eight selected general circulation models were analyzed for minimum, maximum, and average temperatures for two different time slices (2036–2045 and 2045–2065) and for two different emissions scenarios. With climate change, it is projected that average daily ambient temperature over the period 2045–2065 will increase by 2.8°C to 3.4°C in the Mekong Delta. While average temperature always remains below the design temperature without climate change, it is projected that average temperature could slightly exceed the station design temperature for most of the year in the climate change scenario. Changes will also occur in maximum daily temperatures. Under typical historic conditions, mean maximum daily temperatures are below the plant design temperature 66.0% of the year. By the end of the plant economic design life, the maximum daily temperature will exceed 30.0°C year-round, reaching temperatures of up to 35.6°C. It is estimated that with climate change, average daily temperatures could be greater than the plant design temperature for approximately 5.5% of the year.

Frequency Distribution Curves of Daily Temperatures under Baseline and Climate Change Scenarios



A similar analysis was undertaken to assess the extent and impacts of changes in water temperature. In particular, the analysis showed a significant decrease in the proportion of the year when river water temperature is at or below the design temperature of 29.2°C. Under historic average and extreme flood years, the water temperature at the O MON IV intake will be equal to or below the design temperature for 46% to 70% of the year. With climate change influences, the average river water temperature will rarely be below the design temperature of 29.2°C.

Frequency Distribution Curves of Average Daily River Water Temperatures under Baseline and Climate Change Scenarios



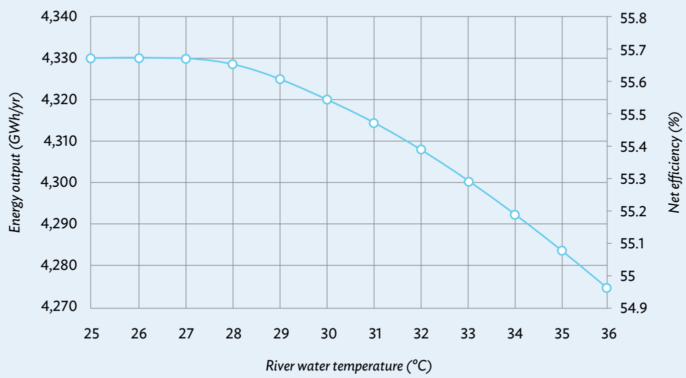
Assessing the potential impacts of increased air and water temperature. According to existing literature (referred to in ADB 2012), with each one-degree temperature increase above 30°C, power output of the gas turbines drops by 0.50% to 1.02% while efficiency drops by approximately 0.24%. Steam turbine power output and efficiency are not significantly changed by changing air temperature, while net power output drops by 0.30% to 0.60% and net efficiency drops by approximately 0.01% per degree above 30°C.

Based on this analysis, it was estimated that power output in 2040 could decrease by 74.0 GWh (relative to baseline conditions) due to changes in air temperature alone, or a 1.7% reduction in annual power output compared with the baseline scenario without climate change.

In order to assess the specific impacts these projected changes in river water temperature may have on the plant, detailed simulations were undertaken for O MON IV using the technical specifications in the project technical design document. These simulations varied the temperature of river water at the intake structure to assess the impacts on cooling efficiency. The figure below shows the relative efficiency as a function of river water temperature.

Increasing river water temperature and the resulting efficiency reduction could also have an adverse effect on energy output. Based on this analysis, annual power output in the year 2040 could be reduced by 25.3 GWh due to changes in river water temperature alone, representing a 0.6% reduction in power output. Net efficiency could also decrease by 0.3%.

Relative Efficiency and Energy Output of O MON IV as a Function of River Water Temperature



The analysis shows that total power output could be reduced by approximately 827.5 GWh over the 25-year economic design life from the combined impacts of climate change, with effects more severe in later phases of project operations. Over the design life of the plant this represents a loss in power output of approximately 0.8%.

Source: ADB. 2012. *Adaptation to Climate Change: The Case of a Combined Cycle Power Plant.* Manila.

Climate Proofing Investment Projects

As indicated earlier, this report covers the economic analysis of *climate proofing* investment projects. The context of such analysis is thus of the following nature.

An investment project (e.g., a bridge, a road, a hydropower dam, an urban water supply system) is currently under consideration.

Given the nature of the project or of its location, questions arise as to the possible impacts of projected changes in mean or peak temperature or in extreme precipitation events on the project. More specifically, concerns pertain to the possibility that climate change may adversely impact the overall economic performance of the project by increasing future costs of the project (such as an increase in maintenance or repair costs resulting from more frequent flooding of a road) or by reducing the estimated benefits of the project (for example, the efficiency of a combined cycle power plant may be adversely impacted by an increase in the temperature of surface water used for cooling purposes, or the number of days a road becomes impassible increases as a result of more frequent or more severe flooding). Climate risk screening reveals the project to be at medium or high risk, and a CRVA is conducted. The assessment more precisely identifies the potential impacts of climate change on the project (Box 2), and identifies possible option(s) (if any) to mitigate or alleviate these projected adverse impacts. These options are subjected to a technical feasibility and economic viability analysis. This is what is understood with the expression *climate proofing* investments in this report (Box 3; additional examples specific to the transport sector are presented in ADB 2014c).

In the context of a detailed climate risk and vulnerability assessment, the economic analysis of climate proofing investment projects involves the following key steps:

- assessing the physical impacts of climate change on the project's capacity to deliver services as originally intended—a task requiring expertise of a nature other than economics;
- transforming the identified physical impacts of the climate change into cost of climate change (which may result from an increase in project costs and/or reduction in project benefits);
- assessing the technical feasibility of alternative project design(s) or measures aimed at offsetting the identified adverse impacts—another task requiring expertise of a nature other than economics;
- estimating the *incremental* costs of these alternative design(s);
- for each technically feasible climate-proofing measure, comparing the estimated incremental cost of the measure with the *expected benefits* of the climate-proofing investment; and
- calculating the (expected) net present value of each climate-proofing measure, and making a recommendation.

In this context, a climate-proofing option is defined as an activity aimed at increasing the resilience of the project to climate risk. In economic terms, it is defined as an activity that directly aims at increasing the net present value of the project in the presence of climate change.

It is important to note that climate proofing must imply the consideration of modifications to a project design, such consideration being justified as a result of projected climate change. As such, climate proofing must imply a positive incremental cost to any given project design (for if a modified "climate-proofed" project design were to cost less than its "nonclimate-proofed" original design and yet deliver the same or higher total benefits, then the "climate-proofed" design should have been preferred in the first place, and thus cannot be considered a response to climate change).

Box 3: Examples of Climate Proofing Investment Projects

Khulna Water Supply Project (Bangladesh). A study was conducted to assess the impacts of climate change on the urban water supply system in Khulna and to identify adaptation options to climate proof a proposed water supply investment project. The study found that projected decreases in river flows in the dry season and sea level rise would increase the salinity of the river, an important source of water supply. Two adaptation options were proposed: shifting the water intake point further upstream by 4 kilometers (km) or increasing the size of the impounding reservoir by 12 million cubic meters. A further detailed analysis was conducted to determine the required size of the impounding reservoir. The city has planned to gradually increase the size of the impounding reservoir while continuing the monitoring of the salinity levels in the river (see ADB 2011b for details).

Avatiu Port Development Project (Cook Islands). The $24.6 million project will rehabilitate and expand the capacity of Avatiu Port in the Cook Islands. This involves widening the harbor entrance, dredging to increase the depth alongside the wharf plus dredging and enlarging the ship turning area, and reconstructing and realigning the quay and repairing the adjacent wharf deck. Out of the $24.6 million, $800,000 was earmarked to modify project design so as to allow for future adaptation to the anticipated impact of sea level rise. The revised design involves the strengthening of pilings to provide the load bearing that will be required to raise the wharf level by up to 0.5 meters if there were a need to do so in the future. This method has been selected for economic efficiency and raises the wharf level to an elevation that is more appropriate for current conditions and the larger ships using the port (see ADB 2014c for more details).

Central Mekong Delta Region Connectivity Project (Viet Nam). The Central Mekong Delta Connectivity Project is an $860 million investment to enhance connectivity between agricultural and agroprocessing provinces of southern Viet Nam with major national and regional markets. The project includes two major bridges (Cao Lanh and Van Cong) crossing the Mekong River, and a 15-kilometer road connecting the two bridges. A study was conducted to assess the vulnerability of the project to climate change (in particular sea level rise) and examine possible climate-proofing options. The study found that the embankments of the connecting road (between the two bridges) were vulnerable to the projected increase in frequency and intensity of flooding exacerbated by sea level rise. Projected impacts include (i) erosion of road embankments and scouring of road foundations, (ii) water logging of road foundations leading to road subsidence, (iii) reduced stability of infrastructure, and (iv) increased maintenance effort. Based on these findings, one of the climate-proofing options identified is to raise the current design height of the road embankment by 0.3 meters (see ADB 2014d for more details).

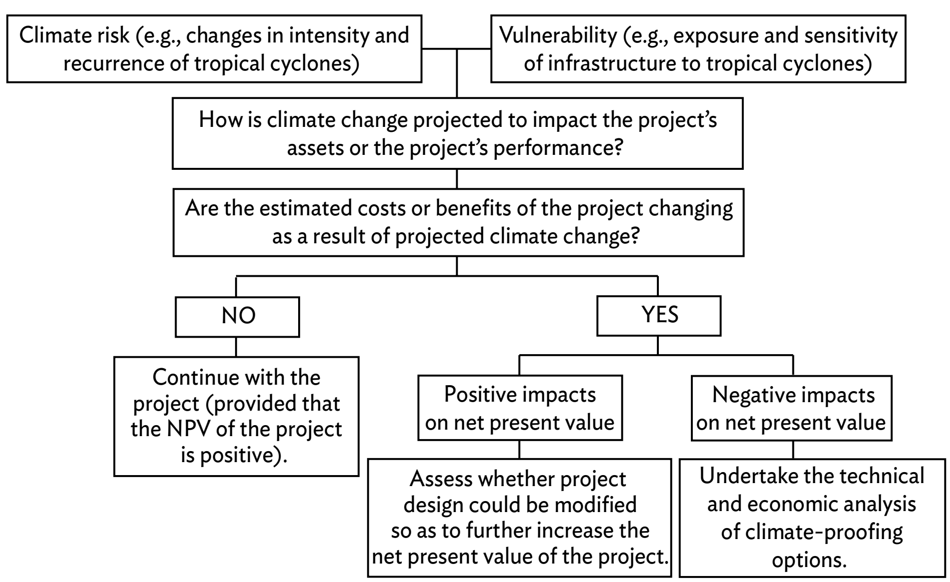
Cost of Climate Change versus Benefits of Climate Proofing

Cost of Climate Change at the Project Level

A key objective of the CRVA is to provide information on the impacts of projected climate change on the project's economic viability. As shown in Figure 3, the outcome of the assessment may reveal that the project's costs and/or benefits may or may not be affected by climate change. In the event that the project's net present value (NPV) is unchanged as a result of climate change, the recommendation would be to proceed with the project provided that the NPV is positive.

On the other hand, as a result of climate change, project costs may be expected to increase (e.g., damages to road and road maintenance costs may be expected to increase as a result of a projected increase in extreme precipitation and flooding, or project benefits may

Figure 3: How Will Climate Change Impact the Project?



be expected to decrease.[17] It is in those circumstances that the technical and economic analysis of climate proofing is of interest.

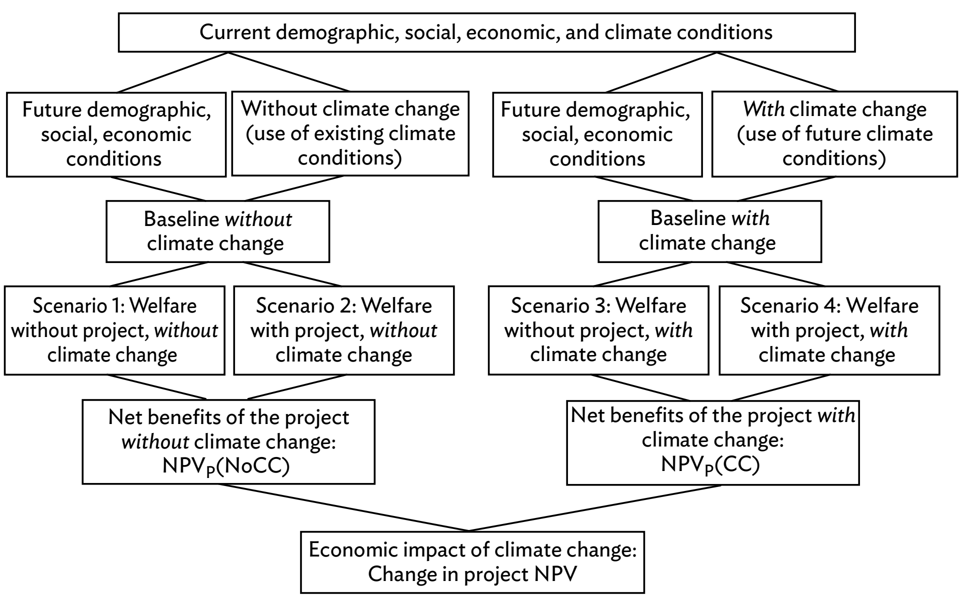
As illustrated in Figure 4, at the project level, a traditional approach is to estimate the NPV of an investment project in the absence of climate change. As described in ADB's guidelines (ADB 1997), such an estimate is performed by comparing society's welfare with and without the project (Scenario 1 versus Scenario 2). The difference between these two scenarios is the NPV of the project (noted NPV_P) in the (assumed) absence of climate change (noted $NPV_P(NoCC)$). Similar with and without project scenarios are then developed in the presence of climate change (Scenario 3 and Scenario 4) with the resulting outcome being the NPV of the project in the presence of climate change (noted $NPV_P(CC)$).

The *economic cost of climate change* (before any consideration of any form of adaptation) is measured as the reduction in the NPV of the project as a result of climate change, and is measured as $[NPV_P(NoCC) - NPV_P(CC)]$.

As indicated earlier, for the purpose of this report, it is assumed that climate change is costly to the project, i.e., it is assumed that $NPV_P(NoCC) > NPV_P(CC)$.

A stylized example is presented in Box 4.

Figure 4: Economic Impact of Climate Change



17 In principle, one cannot exclude the possibility that in some specific circumstances, climate change may reduce the costs or increase the benefits of an investment project. However, in most circumstances this is not expected to be the case (as is implicitly reflected in estimates of the global economic costs of climate change). Hence, for the purpose of this report, it is assumed that climate change is projected to adversely impact the economic viability of an investment project.

Box 4: Example 1: Computing the Economic Cost of Climate Change

A road project is currently under consideration in a mountainous area of the Mekong River Basin. Project construction is expected to take 3 years. The capital cost is estimated to be $20 million per year for each of the 3 years of the project. Once completed, the infrastructure has an estimated lifetime of 25 years and a residual value of zero. Annual (recurrent) operation and maintenance costs are projected to reach $2 million per year from Year 4 to Year 28 (25-year lifetime). Benefits of the project (resulting from reduced vehicle operation cost, reduced travel time, and economic benefit of an increase in the number of trips) have been estimated to reach $15 million per year from Year 4 to Year 28.

Without climate change. Historical records show that 10 severe flood events have been experienced over the course of the last 50 years in the region where the project will take place. On this basis, the probability of a severe flood in any given year is estimated to be 20% (10/50). Based on historical records, it is estimated that the typical repair cost following each flood event of this magnitude has been on average $5 million (measured in today's dollars). Given this information, the *expected* annual repair cost (associated solely with the flood event, as distinct from the normal operation and maintenance cost) is estimated to be $1 million (20% * $5 million).

The NPV of the project depends on the discount rate being used. For purpose of this example (and all other examples presented in this report), a discount rate of 12% is used (per ADB's requirement—a discussion on the selection of the discount rate is presented later in the report). Given the above information, the NPV of the project (in millions of dollars) without climate change is:

NPV_P(NoCC)	**$18.95**

The NPV being positive, the recommendation is to proceed with the project on the grounds of economic efficiency.

With climate change. Experts have projected that climate change will considerably increase both the frequency of flood events and the intensity of each event in the coming decades. Discussions with meteorological experts and transport engineers indicate that the *expected* annual repair cost may increase from the estimated $1 million to $2 million over the lifetime of the project infrastructure (as a result of either an increase in the frequency of severe flood events or of higher damages resulting from each event).

While this increase in expected annual repair cost may take place gradually over time, the local project appraisal team opts to include this higher expected annual repair cost from the very beginning of the project (Year 4)—a ***worst case scenario*** (the rationale being that if the NPV of the project were to remain positive under this worst case scenario, then it would remain positive under any other scenario involving a gradual increase in expected annual repair cost). Given the above assumptions, the revised NPV under this worst case scenario is:

NPV_P(CC)	**$13.37**

The NPV of the project falls but remain positive. If there were to be no technically feasible form of climate proofing to address the issue, one would recommend proceeding with the project, albeit with a reduced (but positive) NPV.

continued on next page

Box 4: continued

Cost of climate change. The cost of climate change is computed as the reduction in the NPV of the project resulting from the increase in expected annual repair cost, that is the difference between $NPV_P(NoCC)$ and $NPV_P(CC)$. Given the above assumptions, the cost of climate change is:

Cost of climate change [NPVP(NoCC) – NPVP(CC)]	**$5.58**

Sensitivity analysis: Switching value. It may be argued that considerable uncertainty remains as to the impact of climate change on the frequency or intensity of future flood events and therefore on the resulting change in annual repair cost. A sensitivity analysis aims to increase the level of confidence in the nature of the recommendation (to proceed with the project) in presence of uncertainty. Different types of sensitivity analyses may be conducted, and these will be discussed in greater detail further in this report. One such type is referred to as *switching value analysis*, which involves estimating the value of the parameter of interest for which the NPV of the project becomes nil (0). In the context of the above example, with respect to expected annual repair cost, the switching value is the value of the expected annual repair cost, which would bring $NPV_P(CC)$ to zero. The switching value is $4.4 million—if expected annual repair cost were estimated to be $4.4 million in every year of the project's lifetime, then $NPV_P(CC)$ would become 0. Discussions with local meteorological experts, engineers, and other informed stakeholders would aim to identify the likelihood for the expected annual repair cost to reach this value. The switching value analysis does not reduce the need to look into the future, but it does so in a different manner. Instead of asking for an estimate of future annual repair cost in the presence of climate change, the switching value analysis provides such a number (the maximum the annual repair cost the project could sustain before its NPV becomes negative), and asks the question: What's the likelihood that a number of this magnitude will be reached given our assumptions about climate change?

Once (if) it has been determined that the NPV of the investment project is adversely impacted by projected changes in climate conditions, then there arise considerations of mitigating those impacts: how, how much, and when.

Benefits of Climate Proofing

A key objective of a cost–benefit analysis is to estimate the net benefits of climate-proofing measures.

At the project level, it is important to distinguish between (i) the costs of climate change and (ii) the benefits of climate proofing. As illustrated in Figure 5, given a scenario with climate change, the impact of climate proofing is estimated as the difference between the NPV of the project *without* climate proofing (noted $NPV_P(NoCP)$—where CP stands for climate proofing) and the NPV of the project *with* climate proofing ($NPV_P[CP]$)—where $NPV_P(CP)$ includes the cost of climate proofing.

A key feature of the approach is to recognize that the costs and benefits of the climate-proofing options must be assessed by identifying and quantifying the climate change impacts along two scenarios:

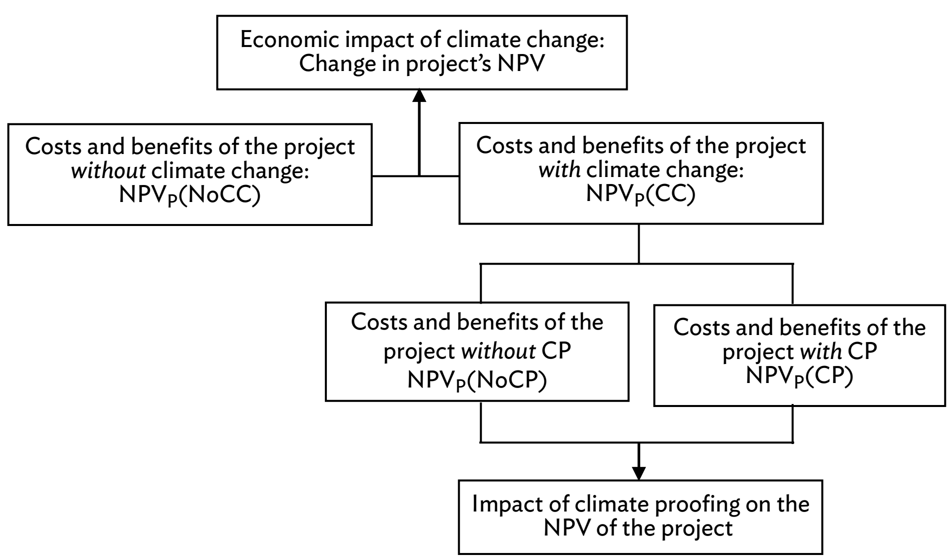
- **Scenario without adaptation:** What are the *expected* impacts of climate change on the project *in the future* if there were to be no climate-proofing measures in place?
- **Scenario with adaptation:** What are the *expected* impacts of climate change on the project *in the future* if there were to be climate-proofing measures in place?

Provided the above notation, note that $NPV_p(CP)$ stands for the NPV of the entire investment project, and not solely of the climate-proofing measure. In other words, NPV_p includes the costs and the benefits of both the project and the climate-proofing measure. Also note that $NPV_p(CP)$ is assumed to include *all* economic benefits resulting from the adoption of the climate-proofing measure, including ancillary or cobenefits (which are discussed in more detail below).

Note the following:

- In the presence of climate change, the NPV of the project without climate proofing is identical to the NPV of the project with climate change as defined above, i.e., $NPV_p(NoCP) = NPV_p(CC)$.
- In order to assess the desirability of climate proofing an investment project, the NPV of the project without climate change, $NPV_p(NoCC)$, is of no relevance. In other words, the baseline against which the benefits of adaptation measures are to be assessed is one *with* climate change, and not an imaginary baseline without climate change. While the NPV of the project without climate change may be of interest to assess the impacts of climate change on the project, this NPV should not be used to assess the benefits of climate proofing.
- The economic impact of a climate-proofing measure is estimated as the difference between $NPV_p(NoCP)$ and $NPV_p(CP)$. The net benefit of climate proofing is estimated as $[NPV_p(CP) - NPV_p(NoCP)]$. Investing in a climate-proofing measure will be

Figure 5: Impact of Climate Change and of Climate Proofing



recommended if $NPV_P(CP)$ is larger than $NPV_P(NoCP)$. If $NPV_P(NoCP)$ were to be larger than $NPV_P(CP)$, then climate proofing would not be recommended.

- One could consider de-linking the project and the climate-proofing option and consider undertaking the economic analysis of climate proofing options only. Assume for a moment that $NPV_P(CP)$ does *not* include the cost of the climate-proofing option, and note by C(CP) the incremental cost of the climate proofing option in present value terms.[18] Then, the benefit of the climate-proofing measure would be measured as $[NPV_P(CP) - NPV_P(NoCP)]$, and the *net* benefit would be measured as $\{[NPV_P(CP) - NPV_P(NoCP)] - C(CP)\}$. Without loss of generality and unless otherwise clearly indicated, we will continue to assume that NPV_P includes the cost of the climate-proofing option.

Box 5 illustrates the computation of the economic impact of climate proofing in the context of the stylized example presented in Box 4.

Box 5: Example 2: Computing the Economic Impact of Climate Proofing

In the example in Box 4, once the impacts of climate change had been assessed on the project's NPV, it was then determined (in consultation with road engineers) that improved road drainage could be designed and implemented in order to reduce damages resulting from flood events in the region.

If the measure were to be implemented, the expected annual repair cost would be reduced from the estimated $2 million to $1 million—by coincidence, the same level for each option, and the same level as in the absence of climate change—thereby completely offsetting the impacts of climate change on expected annual repair cost.

The improved road drainage system would increase the project annual capital cost from $20 million to $21 million in each of the first 3 years of the project. For simplicity, it is assumed that operational costs remain the same (no incremental operational cost as a result of the climate-proofing measure). The benefits of reduced expected annual repair cost would start to occur in Year 4.

Net benefit of climate proofing

Given the above information, the NPV (in $ millions) of the project with the climate-proofing measures in place are estimated as follows:

NPV_P (NoCP)—as in Box 4	**$13.37**
NPV_P(CP; improved drainage)	**$16.55**
Net benefits of climate proofing $NPV_P(CP) - NPV_P(NoCP)$	**$3.18**

Given that $NPV_P(CP)$ is larger than $NPV_P(NoCP)$, then one would recommend going ahead with the project with improved drainage.

continued on next page

[18] In addition to the initial capital cost, the climate-proofing option may entail increases in annual operational costs that must also be accounted for. Hence, it is more accurate to think of the cost of the climate-proofing option in present value terms.

Box 5: continued

In the above example, note that if the project capital cost with improved drainage were to be higher than $22.3 million in each of the first 3 years of the project (improved drainage costing $2.3 million or more), then the NPV of the project with drainage would become lower than $13.37. If "improved drainage" were to be the only technically feasible climate-proofing option, then one would recommend going ahead with the project *without* climate proofing.

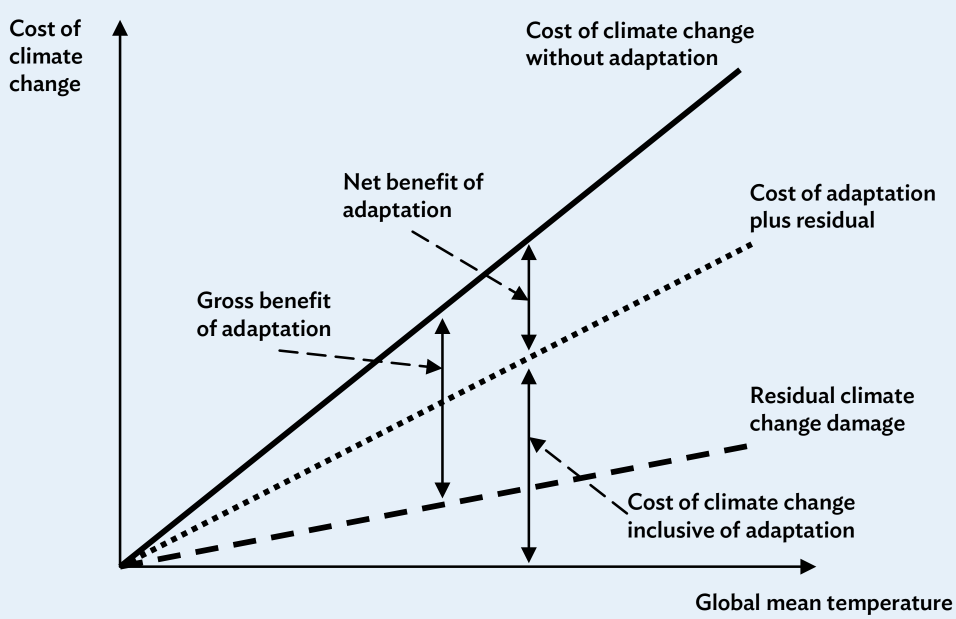
Residual Damage

It cannot be presumed that the implementation of the climate-proofing measure will allow the project, in the presence of climate change, to recover all of the net present value it lost as a result of climate change (and reach NPV_p(NoCC)).

This reduction in NPV, even after allowing for the economically efficient climate-proofing measure, is akin to the concept of *residual damage* introduced by Stern (2007), where residual damage is defined in the climate change literature as the remaining impacts (cost) of climate change *after* adaptation is implemented (Box 6).

Box 6: Adaptation and Residual Damage

While adaptation will reduce the impacts of climate change, there will almost always be residual damage. As noted in Stern (2007), the gross benefit of adaptation is the damage avoided. The net benefit of adaptation is the damage avoided, less the cost of adaptation.



Source: Stern, N. 2007. *The Economics of Climate Change: The Stern Review.* New York: Cambridge University Press.

At the project level, assuming that climate proofing is beneficial to the project [$NPV_P(CP) > NPV_P(NoCP)$], then the residual damage from climate change is defined as the difference between the NPV of the project without climate change ($NPV_P(NoCC)$, and the NPV of the project under climate change with climate proofing ($NPV_P[CP]$).

The above is illustrated in Box 7.

Box 7: Example 3: Residual Damage

In the above road transport example (Box 5), climate proofing has been deemed beneficial ($NPV_P(CP) > NPV_P(NoCP)$). However, note that even with climate proofing, the NPV of the project remains lower than the estimated NPV of the project *without* climate change. This loss in net present value (economic welfare) is the estimated residual damage.

	NPVp	Residual Damage
$NPV_P(NoCC)$	\$18.95	-
$NPV_P(CP)$	\$16.55	\$2.40

A summary of the above discussion is presented in Table 1.

Once climate proofing is included in the analysis, the cost of climate change is measured as the sum of the cost of climate proofing and residual damages (Box 8).

In addition to the costs and benefits of climate proofing to the project performance, the economic analysis of alternative climate-proofing options must also account for the following two important costs or benefits that may arise: ancillary benefits and the cost of maladaptation. These are briefly discussed below.

Table 1: Economic Impact of Climate Change, Climate Proofing, and Residual Damage

Type of Impact	To Compare	Nature of Impact
Economic impact of climate change	$NPV_P(NoCC)$ vs $NPV_P(CC)$	Positive impact if $NPV_P(NoCC) < NPV_P(CC)$ Negative impact if $NPV_P(NoCC) > NPV_P(CC)$
Economic impact of climate proofing	$NPV_P(NoCP)$ vs $NPV_P(CP)$	Positive impact if $NPV_P(CP) > NPV_P(NoCP)$ Negative impact if $NPV_P(CP) < NPV_P(NoCP)$
Residual damage	$NPV_P(NoCC)$ vs $NPV_P(CP)$ or $NPV_P(NoCP)$	Residual damage equals $NPV_P(NoCC) - \max[NPV_P(CP), NPV_P(NoCP)]$

Box 8: Cost of Climate Change, Benefits of Climate Proofing, and Residual Damages in Europe

The European Environment Agency has published the following estimates of climate change costs, adaptation costs, and residual damages (at the macroeconomic level). All numbers below are presented in billions of euros per year.

			Residual Damages			Costs of Climate Change	
Climate Change Scenario	Damage Costs without Adaptation (A)	Adaptation Costs (B)	Without Adaptation (C)	With Adaptation (D)	Benefits of Adaptation (E)	Without Adaptation (F)	With Adaptation (G)
A2							
2030	4.8	1.7	4.8	1.9	2.9	4.8	3.6
2050	6.5	2.3	6.5	2.0	4.5	6.5	4.3
2100	16.9	3.5	16.9	2.3	14.6	16.9	5.8
B1							
2030	5.7	1.6	5.7	1.6	4.1	5.7	3.2
2050	8.2	1.9	8.2	1.5	6.7	8.2	3.4
2100	17.5	2.6	17.5	1.9	15.6	17.5	4.5

In the above table, note the following:

- Damage costs without adaptation (A) = Residual damages without adaptation (C) = Costs of climate change without adaptation (F).
- Benefits of adaptation (E) = Residual damages without adaptation (C) – Residual damages with adaptation (D).
- Costs of climate change with adaptation (G) = Adaptation costs (B) + Residual damages with adaptation (D).

Source: Adapted from European Environment Agency. 2010. *The European Environment State and Outlook 2010: Adapting to Climate Change*. Copenhagen: EEA.

Ancillary Benefits and Ecosystem-Based Climate-Proofing Measures

While all options shall primarily aim to climate proof specific investments, (though different options may do this to various degrees), some options may also deliver economic benefits additional to the climate-proofing benefits to the project itself. These additional benefits are generally referred as cobenefits or ancillary benefits[19]

[19] In its Fifth Assessment Report, the IPCC (2014) defines cobenefits as "[t]he positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. Cobenefits are often subject to uncertainty and depend on local circumstances and implementation practices. Cobenefits are also called ancillary benefits." In this context, please note that ancillary benefits in the existing context are not meant to include the economic value of global public good environmental benefits, according to the national focus of ADB's economic analysis procedures for investments.

For example, the reforestation of a hillside in order to protect a transport infrastructure from landslides may also deliver fruit crops as well as serve as a regulating mechanism for water supply; or the planting of mangrove or restoration of a degraded coastal wetland to protect a coastal road investment project from storm surges may also serve as a habitat for fisheries. There is increasing interest in assessing the potential of ecosystem-based approaches to adaptation and resilience in general, and to climate proofing investment projects in particular. It is, however, also recognized that few studies have attempted to compare the effectiveness (including the economic effectiveness) of ecosystem-based adaptation measures with “hard” infrastructure measures.[20]

If we note by NPV(AncB) the net present value of ancillary benefits associated with a climate-proofing measure,[21] then the net benefit of this climate-proofing option would be measured as $\{[NPV_p(CP) - NPV_p(NoCP)] + NPV(AncB)\}$.

As a general premise, given that the economic analysis of an investment project should aim to include all costs and benefits of the project, positive cobenefits or ancillary benefits need to be accounted for in the economic analysis of climate-proofing options if and when they exist. These will include ancillary benefits associated with ecosystem-based approaches to climate proofing investment projects (Box 9).

Box 9: Example 4: Accounting for Ancillary Benefits of Ecosystem-Based Approaches to Climate Proofing

In the above example (Box 4 and Box 5), in addition to improved drainage to protect the road project, it has also been pointed out that hillside reforestation could provide a similar climate-proofing benefit to the road. In addition to these benefits, hillside reforestation could also provide nontimber forest products to local communities.

It has been estimated that hillside reforestation would provide the same climate-proofing benefits as improved drainage by reducing expected annual repair cost from the estimated $2 million to $1 million.

The improved road drainage system would increase the project capital cost from $20 million to $21 million in each of the first 3 years of the project. The hillside reforestation option would increase the project capital cost from $20 million to $22 million in each of the first 3 years of the project (the improved drainage system was assumed to increase the project capital cost from $20 million to $21 million). Unlike that improved drainage, the hillside reforestation option would also entail an increase in operational cost starting in Year 4 from $2 million to $2.2 million. However, in addition to the reduction in expected annual repair cost, the hillside reforestation project would provide additional benefits in the form of nontimber forest products. The economic value of these goods is estimated to be $2 million. However, agriculture experts point out that these ancillary benefits would start being realized only in Year 10 of the project time horizon.

continued on next page

[20] Detailed discussions of ecosystem-based approaches are found in Jones et al. (2012), Munang et al. (2013), Ojea (2013), and Travers et al. (2012).

[21] We prefer to refer to the net present value of the ancillary benefits as opposed to simply the present value of the ancillary benefits as capturing these benefits may entail operation costs of their own.

Box 9: continued

With climate change—with climate proofing measure

For the purpose of this example, assume that the time horizon of both climate-proofing measures is similar to the time horizon of the project itself, which is 25 years (a more detailed discussion of time horizon is presented later in this report). Given the above information, the NPV of the project with the climate-proofing measures in place are estimated as:

NPV_P(improved drainage)	**\$16.55**
NPV_P(hillside reforestation)	**\$18.35**

Economic benefit of climate-proofing measures

The economic benefit of the climate-proofing measure is estimated as the change in the NPV of the project *with* climate proofing versus *without* climate proofing (NPV_P(CP) – NPV_P(NoCP)). The economic benefit is:

Economic benefit of improved drainage	**\$3.18**
Economic benefit of hillside reforestation	**\$4.97**

Note in the above example that in and of itself, the hillside reforestation option (without including the benefits of climate proofing the road project) would not have been justified as it would yield a *negative* NPV of \$0.61 million. It is in this sense that this option is considered a climate-proofing option (and not, for example, an agricultural or environmental project): It would not be economically justified without those climate-proofing benefits.

On the basis of the above information, based solely on economic efficiency, hillside reforestation would be the recommended option.

Sensitivity analysis: Switching value 1

In the context of the above example, discussions with agricultural and forestry experts have led to estimating the ancillary annual benefits of the hillside reforestation projects at \$2 million. However, it was also pointed out that there is some uncertainty as to the extent of those benefits, and that if these ancillary benefits were to be much lower, then the improved drainage could very well be the preferred climate-proofing measure. One may estimate the value of the ancillary benefits that would lead the recommendation to *switch* from recommending hillside reforestation to recommending improved drainage. Given the other parameters of this example, this switching value is approximately \$1.3 million. In other words, if the annual ancillary benefits are expected to be at least \$1.3 million, then the hillside reforestation option is preferred; on the other hand, if these annual ancillary benefits are more likely to be below \$1.3 million, then the improved drainage would be the preferred option.

Sensitivity analysis: Switching value 2

In the context of the above example, discussions with agricultural and forestry experts have led to estimating that the ancillary annual benefits of the hillside reforestation projects would begin in Year 10 of the project. However, it was also pointed out that there is some uncertainty as to this estimate. Benefits could start earlier (in which case the hillside reforestation measure would certainly continue to be the preferred option), or later (in which case the improved drainage measure may be preferred if indeed the ancillary benefits of the hillside reforestation

continued on next page

Box 9: continued

measure were to be much delayed). One may estimate the number of years which would lead the recommendation to switch from recommending hillside reforestation to recommending improved drainage. Given the other parameters of this example, this switching value is approximately 13 years. In other words, if the hillside reforestation measure were to start delivering ancillary benefits no more than 13 years after the start-up of project implementation, then hillside reforestation is the preferred measure; on the other hand, if these ancillary benefits are expected to start beyond 13 years after start-up, then improved drainage would be the preferred option.

Maladaptation

While all options shall aim to climate proof specific sector investments, some options may do so at the expense of other sectors of the economy. For example, a floodwater diversion option may keep a transport infrastructure functional but increase flooding in the area where water is being diverted.

In its Fifth Assessment Report, the IPCC defines maladaptation or maladaptive actions as "actions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future" (IPCC 2014). Barnett and O'Neill (2010) define maladaptation as "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups."[22]

These adverse outcomes on other systems or social groups, whether intentional or not, negatively impact social welfare. As such, a general premise of the economic analysis is that to the extent that such outcomes can be identified, quantified, and valued, they need to be accounted for as costs in the cost–benefit analysis of climate-proofing options (Adger et al. 2005).

Time Horizon

The selection of the time horizon over which to conduct the economic analysis of an investment project is a key feature of any economic analysis, and is of particular interest in the context of climate change, which is projected to span numerous decades if not centuries.

In principle, in any economic analysis, the time horizon of the analysis (the end point or end year) should coincide with the duration of the (positive or negative) welfare impacts of the project, and capture all important effects for as long as they last. This may or may not

22 Alternative definitions of maladaptation are provided in OECD (2009), Olhoff and Schaer (2010), and Scheraga and Grambsch (1998).

coincide with the expected lifetime of a project's infrastructure.[23] In theory, the longer the time horizon, the more likely the economic analysis will capture all costs and benefits of the project. If the time horizon of the analysis is truncated, then a residual or terminal value should be estimated and discounted to its present value term.

However, the longer the time horizon, the more uncertain becomes the assessment of the impacts of the project, and thereby its costs and benefits. The need to account for all costs and benefits must therefore be traded off with a greater level of uncertainty as the analysis extends in the future. A discussion pertaining to the appropriate setting of the time horizon into the economic analysis is beyond the scope of this report; it best belongs to ADB's guidelines on the conduct of projects' economic analysis. In practice, the time horizon in existing economic analyses is selected to coincide with

- the expected lifetime of the project key infrastructure component, or
- the "economic" lifetime of the project infrastructure, or
- the duration of the concession granted to a concessionaire.[24]

With respect to the economic analysis of climate proofing investment projects, the following guidance is provided.

First, in circumstances where a climate-proofing measure pertains to modifications to project design or similarly in circumstances where a climate-proofing measure provides no benefit other than those provided to the investment project itself, then the time horizon for the analysis of the climate-proofing measure should coincide with the time horizon of the investment project itself—regardless of how this time horizon is set. Selecting a longer time horizon would implicitly assume that the climate-proofing measure provides benefits to a project which, for the purpose of analysis, has ceased to exist.

Second, in circumstances where a climate-proofing measure provides ancillary benefits (as discussed above), the economic analysis of the climate-proofing measure could adopt a time horizon to coincide with the lifetime of the climate-proofing measure itself. In such circumstances, the benefits associated with the climate proofing of the investment project extend to the selected lifetime of the investment project, while the ancillary benefits will extend to the lifetime of the climate-proofing measure (Box 10).

The significance of the selection of the time horizon of the economic analysis is not unrelated to the selection of the discount rate discussed in the next section.

---

[23] For example, a project's environmental impacts may extend beyond the lifetime of a project's infrastructure (and certainly do so when those impacts are irreversible). Truncating the analysis to coincide with the lifetime of the project's infrastructure implicitly assumes that such impacts (positive or negative) also end with the project, and that the flow of goods and services provided by ecosystems returns to its preproject level.

[24] A review of the selected time horizons in the economic analysis of ADB-financed investment projects is presented in Appendix 1. One notes that in most instances, the time horizon selected is 20 to 30 years, and that terminal values are occasionally estimated or explicitly assumed to be zero. In the larger number of cases, terminal values are not discussed.

Box 10: Example 5: Ancillary Benefits and Project Lifetime

In Box 9, it was assumed that a hillside reforestation measure could provide a climate-proofing benefit to the road project similar to that of an improved drainage system—reducing expected annual road repair cost from the estimated $2 million to $1 million. As described in Box 9, the investment cost of this climate-proofing measure is estimated to be $2 million in each of the first 3 years of the project; operational costs are estimated to be $0.2 million.

In addition to these benefits, hillside reforestation could also provide nontimber forest products to local communities (ancillary benefits). These were estimated to be $2 million per year, starting in Year 10 of the project time horizon.

In Box 9, it was assumed that that the time horizon of both climate-proofing measures was similar to the time horizon of the project itself, which is 25 years. While this was an appropriate assumption for the improved drainage system (which projects no benefit other than climate proofing the road infrastructure), agriculture experts suggest that the ancillary benefits provided by the reforestation measure may extend for a period of 40 years (the expected lifetime of the trees).

The flow of costs and benefits pertaining to the hillside reforestation climate-proofing measure is presented below. Note that the climate-proofing benefits to the road infrastructure project (reduction of $1 million per year in expected annual repair cost) ends in Year 28, along with the assumed lifetime of the road infrastructure itself.

Year	1	2	3	...	9	10	11	...	27	28	29	...	39	40
Cost ($ millions)	2	2	2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Benefits to road	0	0	0	1	1	1	1	1	1	1	0	0	0	0
Ancillary benefits	0	0	0	0	0	2	2	2	2	2	2	2	2	2

Economic (Social) Discount Rate

The selection of a rate at which to discount future economic costs and benefits of an investment project is arguably one of the issues in cost–benefit analysis that has raised the most attention and controversy, perhaps more so following the publication and review of the Stern report (Stern 2007, Nordhaus 2007, and Weitzman 2007). With sufficiently high discount rates, the economic consequences of disaster events appear small if they happen sufficiently far in the future.[25]

Some authors argue that the setting of the economic discount rate should be based on the economic (social) opportunity cost of capital (Burgess and Zerbe 2011 and Zerbe et al. 2011). Others recommend that the discount rate be based on the rate of social time preference (occasionally also referred as “society’s rate for time preference” or “the

[25] Consider a project that entails an expected cost (or damage) of $100 million in the 50th year of its lifetime. The present value (in $ millions) of this expected cost is as follows (discount rate in parentheses): $60.80 (1%); $14.10 (4%); $2.10 (8%); $0.85 (10%); and $0.34 (12%).

consumption rate of discount").[26] A number of countries (including France, Germany, and the United Kingdom) now set the required discount rate for public sector investment projects based on this concept (Cropper 2012 and Moore et al. 2013). This practice has generally led to a significant reduction in the discount rate used in the economic analysis of public sector investment projects.[27]

For purpose of comparability across economic analysis of investment projects, institutions such as ADB and the World Bank request that specific discount rates be used in the context of the economic analysis of investment projects. While the required rates are relatively similar (10% by the World Bank and 12% by ADB), the rationale underlying these specific values is significantly different.

ADB justifies the rationale of its choice of discount rate on the economic opportunity cost of capital:

> The economic justification of the project is based on comparing the benefits and costs as they occur over time and appropriately discounted. A project investment is economically justified if the estimated economic internal rate of return (IRR) exceeds the economic opportunity cost of capital (EOCC) for the country. Given the difficulty of estimating country-specific EOCCs, the EOCC for all ADB DMCs is 12%. An economic IRR between 10% and 12% is acceptable if there are significant unquantified net benefits (ADB 2013c).

The World Bank justifies its selected value of discount rate as a means of rationing access to subsidized funding:

> The World Bank has not calculated a discount rate but has used 10%–12% as a notional figure for evaluating Bank-financed projects. This notional figure is not necessarily the opportunity cost of capital in borrower countries, but is more properly viewed as a rationing device for World Bank funds. Task managers may use a different discount rate, as long as departures from the 10%–12% rate have been justified in the Country Assistance Strategy (Belli et al. 1998).

Regardless of the justification provided for the use of a specific discount rate, all projects funded by ADB must be evaluated using the same discount rate whether or not the project design is modified to respond to climate change risk.[28] Similarly, the economic analysis of climate-proofing options, when such options are considered on their own as separate incremental investments, must use the same discount rate as is used in the economic analysis of the investment project itself. This will remain the case unless a precise directive

---

26 A comprehensive discussion of the issues of the discount rate is presented in Chapter 3 of ADB (2013e).

27 For example, the United Kingdom lowered its discount rate 6.0% to 3.5%; Germany from 4% to 3%; and France from 8% to 4% (Moore et al. 2013). Further details on the issue of the discount rate are presented in Appendix 2 and in ADB (2013e).

28 A similar conclusion is provided in cost–benefit analysis guidance prepared by H.M. Treasury (2009) for accounting for climate change impacts: "Costs and benefits should be discounted at the standard Green Book discount rate."

is issued allowing for a different approach. It is beyond the scope of this report to suggest or recommend such an approach.[29]

Decision Rule

When undertaking a cost–benefit analysis, numerous criteria have been and continue to be used to assess the overall economic desirability (or viability) of investment projects. In addition to the NPV criterion, the economic internal rate of return (EIRR) remains a common criterion, while the benefit-cost ratio (BCR) is generally less used, albeit often mentioned as an additional criterion (all three criteria are referred to in ADB's guidelines).

The NPV criterion requires computing the difference between the present value of benefits and costs, while the BCR criterion requires computing the ratio of the present value of benefits and costs. The EIRR is the specific value of the discount rate for which the project's NPV is zero. The decision rule for each criterion is indicated in Table 2.

In circumstances where only one project (or project design) is under consideration, or similarly in circumstances where only one technically feasible climate-proofing option is

Table 2: Assessment Criteria and Decision Rule

Criterion	Definition	Decision Rule
Net Present Value (NPV)	Present value of benefits minus present value of costs: $$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$ where B_t and C_t are respectively the expected benefit and cost of the project in year t; r is the required discount rate, and T is the last year of time horizon over which the analysis is conducted.	*General rule:* • Recommend implementing all projects with positive NPV and reject all projects with negative NPV. • In case of mutually exclusive projects and only one project can proceed, recommend the implementation of the project with the highest NPV. *In the context of climate proofing where only one climate-proofing option is available:* • Recommend climate proofing the investment project if the NPV of the project with climate proofing is positive and larger than the NPV of the project without climate proofing. • In circumstances where the climate-proofing option is considered as an incremental investment of its own, recommend adopting the option if its NPV is positive. *In the context of climate proofing where multiple mutually exclusive climate-proofing options are available:* • Recommend adopting the climate-proofing option for which the project's NPV with climate proofing is the largest, provided that it is larger than the NPV of the project without climate proofing. • In circumstances where climate-proofing alternatives are considered as incremental investments of their own, recommend the climate proofing with the highest NPV, provided it is positive.

continued on next page

[29] It may be of interest to note the following recommendation in ADB (2013e): "Finally, for [multilateral development banks] that provide development assistance to developing countries through capital investment, there could be a case for reviewing their decades-old practice of applying a uniform discount rate of 10%–12% to all projects to see whether this practice is still appropriate in a changing world."

Table 2: continued

Economic Internal Rate of Return (EIRR)	Value of the discount rate for which the net present value is 0: $$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+\gamma)^t} = 0$$ where γ is the EIRR	*General rule:* • Recommend implementing all projects for which the EIRR is larger than the required discount rate (assuming that the EIRR exists and that it is unique). • In case of mutually exclusive projects and only one project can proceed, use the NPV decision rule. *In the context of climate proofing where only one climate-proofing option is available:* • Use the NPV rule (as the project with climate proofing and the project without climate proofing may be considered as two mutually exclusive projects). • In circumstances where the climate-proofing option is considered as an incremental investment of its own, recommend the option if its EIRR is larger than the required discount rate. *In the context of climate proofing where multiple mutually exclusive climate-proofing options are available:* • Use the NPV rule.
Benefit-Cost Ratio (BCR)	Present value of benefits divided by present value of costs: $$BCR = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$	*General:* • Recommend implementing all projects with BCR greater than 1. • In case of mutually exclusive projects and only one project can proceed, use the NPV decision rule. *In the context of climate proofing where only one climate-proofing option is available:* • Use the NPV rule (as the project with climate proofing and the project without climate proofing are two mutually exclusive projects). • In circumstances where the climate-proofing option is considered as an incremental investment of its own, recommend the option if its BCR is greater than 1. *In the context of climate proofing where multiple mutually exclusive climate-proofing options are available:* • Use the NPV rule.

available, all three assessment criteria must yield the same outcome and recommendation: if NPV is positive (when estimated at the required discount rate of 10% to 12% per ADB's guidelines), then the benefit-cost ratio must be greater than 1, and the internal rate of return must be greater than 10% to 12%. This is noted in the ADB guidelines (ADB 1997):

> 137. The chosen rate of discount for decision making is between 10% and 12%. At a discount rate within this range, the two main criteria can be used as follows:
>
> - Net Present Value: the discounted value of economic net benefits should be positive. Criterion: Accept all independent projects and subprojects for which the [NPV] is greater than zero.
> - Economic Internal Rate of Return: The economic internal rate of return on resources should exceed that on the next best alternative project. Criterion: Accept all independent projects and subprojects for which for the EIRR is greater than the chosen discount rate.
>
> 138. These two criteria are equivalent. They will lead to the same acceptance and rejection of independent projects and subprojects.

Given the equivalence of the two criteria, ADB's guidelines then proceed with the following decision rule:

> 140. (...) The Bank would expect to:
>
> - accept all independent projects and subproject with an EIRR of at least 12%;
> - accept independent projects and subprojects with an EIRR between 10% and 12% for which additional unvalued benefits can be demonstrated, and where they are expected to exceed unvalued costs;
> - reject independent projects and subprojects with an EIRR between 10% and 12% for which no additional unvalued benefits can be demonstrated, or where unvalued costs are expected to be significant; and
> - reject independent projects and subprojects with an EIRR below 10%.

The decision rules presented above will lead to the same set of decisions and be consistent with a similar set of decision rules if they were presented in terms of NPV (as indicated in Paragraph 138 of the ADB guidelines). However, it is important to note that the equivalence of the two criteria implicitly assumes that the EIRR always exists and that it is always unique. If the assumption holds, then the above decision rule is appropriate and will deliver the same decision as if NPV criterion were to be used. However, such an assumption may not hold.[30]

In circumstances where many projects or project designs or climate-proofing options are available, significant difficulties may emerge with the use of the benefit-cost ratio and the internal rate of return. In particular, BCR may yield to the wrong ranking of mutually exclusive projects of different scales (Box 11), while EIRR may rank mutually exclusive projects or options incorrectly if the time profile of benefits and costs differ across projects.[31] The NPV criterion never yields such misleading ranking of alternatives, and always yields to the selection of the project or option (among mutually exclusive projects or options) which increases society's welfare by most. ADB's *Guidelines for the Economic Analysis of Projects* is very clear on this issue:

> 135. The ranking of project alternatives according to these three criteria may differ. The choice between project alternatives should be made using the economic NPV criterion at the chosen rate of discount, between 10% and 12%.
>
> Criterion: Choose project alternative with the highest NPV at the chosen discount rate (between 10% and 12%).

---

30 This is pointed out in numerous textbooks on economic analysis. See Boardman et al. (2010).

31 For example, one reads in Belli et al. (1998), "Because of its close resemblance to the rate-of-profit notion, the IRR appeals to decision makers; it has long been standard practice at the [World] Bank to select projects and present the results of economic analysis using the IRR. However, when evaluating projects, and especially when selecting alternative designs, analysts should be aware of the limitations of the IRR and use the NPV criterion. The IRR is a useful summary statistic to present the results of analysis, but it is not a good basis for making decisions."

This explains why in this report, reference is mostly made to the NPV criterion to assess the economic desirability of climate-proofing options as in most instances the scenario is one of selecting among mutually exclusive options or alternatives.

The above discussion also points out to the following decision rule as to whether to proceed with the project once having accounted for the impacts of climate change, and whether to proceed with any climate-proofing measure (Figure 6).

Box 11: Net Present Value versus Benefit-Cost Ratio

In the context of case studies on the economics of climate proofing road improvement and development projects in the Pacific, a cost–benefit analysis of five projects was conducted and the net present value (NPV) and benefit-cost ratio (BCR) were estimated (the economic internal rate of return of each project was also estimated but will not be used for the purpose of this box). These are presented below. Note that the projects used in this box simply illustrate the nature of the difficulties one may face upon using the BCR to rank projects.

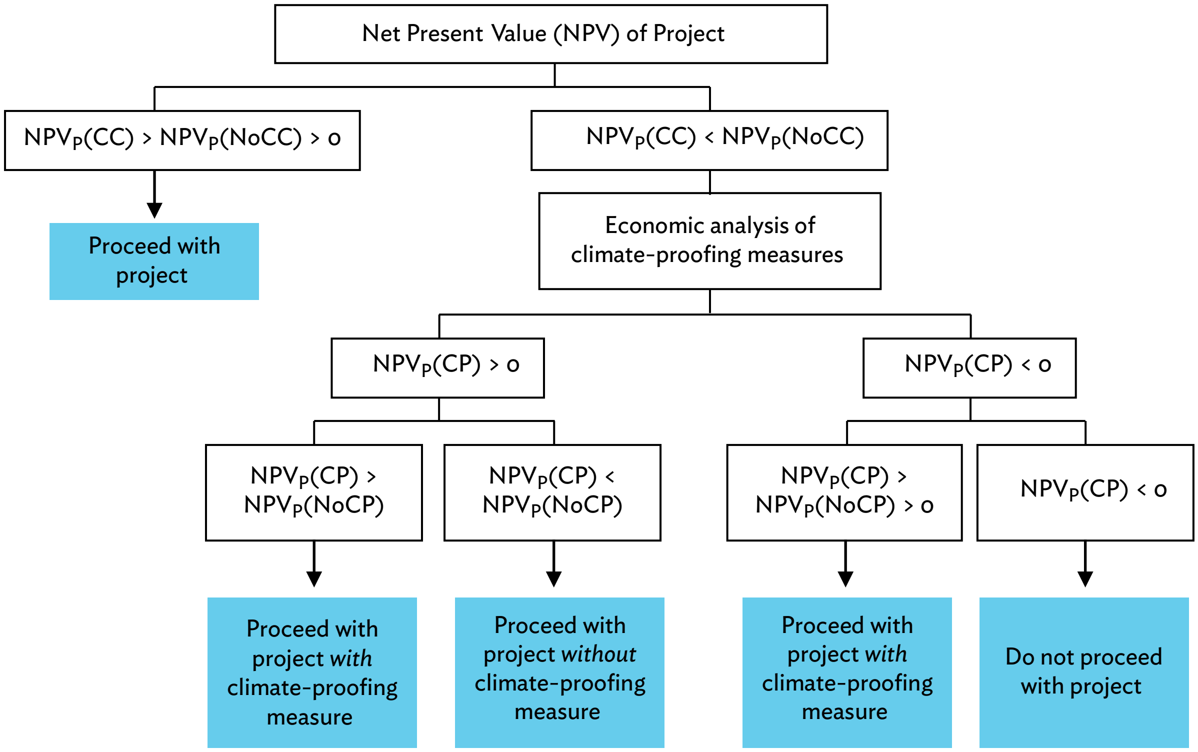
Solomon Islands Second Road Improvement Project		
Northwest Guadalcanal Road Project (29 km)	NPV ($ ‘000)	13,378.4
	BCR	2.73
Makira Island Coastal Road Project (72.5 km)	NPV ($ ‘000)	34,556.6
	BCR	2.94
North Malaita Road Project (31.5 km)	NPV ($ ‘000)	14,452.3
	BCR	2.94
Timor-Leste Road Network Sector Development Project		
Ermera–Maliana Road Project (61.2 km)	NPV ($ ‘000)	58,662.9
	BCR	2.16
Dili–Mota Ain Road Project (78.8 km)	NPV ($ ‘000)	96,794.5
	BCR	2.68

Source: ADB. 2011. *Economics of Climate Proofing at the Project Level: Two Pacific Case Studies.* ADB Pacific Climate Change Program. Manila.

Both the NPV and BCR of these projects conclude similarly and correctly that all five projects, from an economic point of view, should be implemented (all projects deliver a positive NPV; all projects deliver a BCR greater than 1). However, for the purpose of illustration, assume for a moment that only one of these projects could be implemented. A ranking of the projects based on their NPV would clearly indicate that the Dili–Mota Ain Road Project should be implemented as it yields the largest NPV. However, note that the use of the BCR criterion would yield to the selection of the North Malaita Road Project or of the Makira Island Coastal Road Project, which both have a BCR greater than the Dili–Mota Ain Road Project. In fact, based strictly on the BCR criterion, the Dili–Mota Ain Road Project would come in fourth place despite yielding the largest gain in social welfare (as measured by NPV).

Note again the illustrative purpose of this box. The project team was not in a situation of having to recommend the implementation of only one of these five projects. However, it is not entirely uncommon to see an option being selected on the basis of its higher benefit-cost ratio while in fact another option yields a higher NPV; see, for example, Case Study 1 in UNFCCC. 2011. *Assessing the Costs and Benefits of Adaptation Options: an Overview of Approaches*. The Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change. Bonn.

Figure 6: Decision Rule



Note in Figure 6 the following two situations of interest:

First, consider the case where the NPV of the project with climate change remains positive ($NPV_p(CC) > 0$). In such circumstances, the recommendation will be to accept the project—albeit with a reduced NPV—even if no climate-proofing option were to be technically feasible and/or economically viable ($NPV_p(CP) < NPV_p(NoCP)$). Hence, the undertaking of a climate risk and vulnerability assessment does not necessarily lead to the recommendation that climate-proofing measures must be implemented as these measures entail their own costs and benefits.

Second, consider the case where the NPV of the project with climate change becomes negative ($NPV_p(CC) < 0$). In such circumstances, the recommendation will be to abandon the project unless a technically feasible and economically viable climate-proofing option could *potentially* increase $NPV_p(CC)$ to a positive value (where $NPV_p(CC)$ includes the cost of the climate proofing measure itself). Hence, climate change may lead to a situation where, from an economic efficiency point of view, the recommendation would simply be to abandon the project.

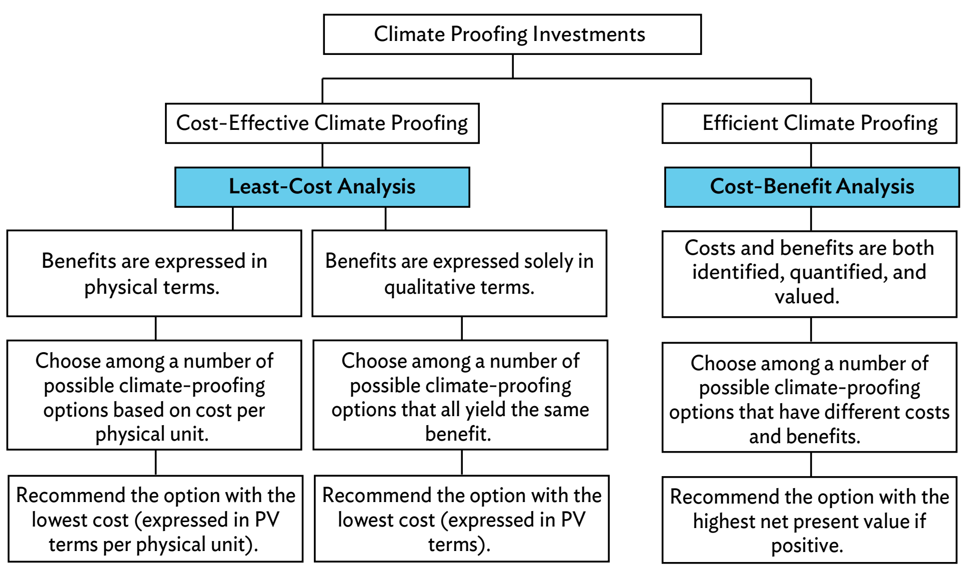
Least-Cost Analysis

In the discussion thus far, it has been assumed that decision making is based on the grounds of economic efficiency, which calls for the use of cost–benefit analysis and for recommendations based on the use of the net present value criterion: (i) recommend the adoption of a climate-proofing measure if its net present value is positive; and (ii) among competing climate-proofing measures, recommend the selection of the measure that provides the largest estimated net present value.

The aim of maximizing economic efficiency explicitly requires that all impacts of the investment be identified, quantified, and valued into costs and benefits. At times, such a benefits assessment process may be difficult. At other times, economic efficiency may not be the only criterion used to guide decision making. In such circumstances, other types of analyses may be required.

A *least-cost* analysis solely aims to assess the economic costs of various climate-proofing options all aimed at achieving a given objective or target. The key strength of a least-cost analysis is that it avoids the estimation of the benefits of climate proofing the investment. Its key weakness arises from its strength: Unlike the cost–benefit analysis, it does not aim to assess whether the investment will deliver a net positive benefit to society as these benefits are not estimated in monetary terms to allow a comparison with the cost of the measure (Figure 7).

Figure 7: Cost–Benefit Analysis versus Least-Cost Analysis



PV = present value.

In the context of climate proofing, the conduct of a least-cost analysis is of particular interest in the following two circumstances:

First, the least-cost analysis is appropriate when two options yield nearly or exactly the same climate-proofing benefits—whether or not this benefit is expressed in monetary values. In such circumstances where the benefits are identical, the use of the least-cost analysis must yield the same ranking of options as would be obtained from the cost–benefit analysis (if the benefits are the same, the least-cost option must also yield the highest net present value). For this reason, the least-cost analysis is especially useful and adequate in the context of climate change mitigation where greenhouse gas abatement options are ranked according to their cost per ton of greenhouse gas abated. In such circumstances, the only element that differentiates options is their respective costs (ignoring that some options may also provide ancillary benefits such as a reduction in local pollutants).

Second, the least-cost analysis is especially relevant when the impacts of climate change may prevent compliance with national standards, thresholds, or regulations. For example, climate change may prevent achieving thresholds for maximum occupational temperatures or for risk of water supply disruption. In other circumstances, climate change impacts may prevent compliance with regional or international treaties (Box 12). In such circumstances, the issue is not whether to climate proof the investment (so as to comply with norms, standards, regulations, or treaties), but more simply to determine how to achieve compliance at least cost. In this situation, the cost (in present value terms) of all available climate-proofing options yielding the same outcome (achieving compliance) should be estimated, and options should be ranked from least cost to highest cost. Unless other factors are deemed of greater importance, the least-cost option will be recommended.

Finally, note that in circumstances where the extent of benefits are different across climate-proofing options but expressed in physical terms (for example, a reduction in the number of hectares of agriculture land or in the number of kilometers of road at risk or in the possible shortfall of water supply), cost metrics can be used to rank climate-proofing options (e.g., cost per hectare of protected agricultural land, per kilometer of protected road, or per cubic meter of water supply).[32] Unless other factors are deemed of greater importance, the option yielding the lowest cost per physical unit will be recommended.

32 See Nicholls et al. (2006) and Rosenzweig and Tubiello (2007) for a discussion of metrics of measurement.

Box 12: Central Mekong Delta Connectivity Project

The Central Mekong Delta Connectivity Project—located in the Mekong Delta of southern Viet Nam—consists of two bridges and an interconnecting road that will form part of a strategic transportation link connecting the provinces of Dong Thap, An Giang, and Can Tho to the Second Southern Highway.

Source: ADB. 2014. *Central Mekong Delta Connectivity Project: Rapid Climate Change Threat and Vulnerability Assessment*. Manila.

Currently, the route crosses the Tien River and the Hau River by ferry, which represents a significant bottleneck, extending journey times considerably. Projected increases in traffic flows would necessitate expansion of ferry capacity (both in terms of the number of boats and in terms of ferry landings). Relative to the no-project scenario, the largest benefit accrues to ferry users by eliminating ferry waiting and crossing time.

The Cao Lanh bridge (crossing the Tien River) will be a cable-stayed bridge with spans 150+350+150 meters (m) and approach bridges with a total length of 682 m on both sides. The Vam Cong bridge (crossing the Hau River) is a cable-stayed bridge with spans 190+450+190 meters and approach bridges with a total length of 1,139 m and 960 m. All approach bridges are made using precast concrete elements. The road section on the bridges is 24.5 m wide. Substructures are made with cast-in-situ concrete. Both bridges are founded on bored piles.

In consultation with the Mekong River Commission, the Government of Viet Nam has set a design constraint for bridge elevation based on providing a minimum navigation clearance of 37.5 m for the 1-in-20-year flood elevation (also referred as the P5% flood—5% annual probability of occurrence). This navigation clearance is set to allow future passage of 10,000 deadweight tonnage vessels upriver to the port of Phnom Penh, Cambodia.

continued on next page

Box 12: continued

Given its low altitude, the Mekong Delta is particularly exposed to climate change, especially as it pertains to sea level rise, storm surges, and increasing precipitation. Concerns were thus raised as to whether projected sea level rise and intensification of storm surges may result in violation of the above design constraint.

Had the analysis indicated a likely violation of the design constraint, then options would have had to be identified to ensure compliance with the design constraint. Among all possible options (if more than a single one), a cost-effectiveness analysis would aim to reveal the least-cost option.

Source: ADB. 2014. *Central Mekong Delta Connectivity Project: Rapid Climate Change Threat and Vulnerability Assessment.* Manila.

PART C Economic Analysis and Decision Making with Uncertain Climate Change

As indicated in Part A of this report, conducting the economic analysis of any investment project, even without consideration of climate change, implies looking into the future and asking what the "universe" of interest (identified as the scope of the analysis) may look like with and without the project. The negative and positive impacts of the project (which, once valued, become components of costs and benefits respectively) are then measured as the difference between these two scenarios.

Looking into the future is to confront incomplete information, risk, and uncertainty. This is true of *all* cost–benefit analyses even in circumstances where climate change is of no consideration.

As pointed out in ADB (2002), the term "risk and uncertainty" tends to be applied generically to the analysis of situations where the values of parameters are unknown, or of situations with unknown outcomes. However, conventional definitions aim to distinguish uncertainty from risk, where uncertainty implies the impossibility of attaching probabilities to any given outcomes (such as, for example, attaching a probability density function over a range of possible losses arising from weather extreme events), while risk implies the possibility of attaching such probabilities.

> In essence, risk is a quantity subject to empirical measurement, while uncertainty is of a nonquantifiable type. In a risk situation, it is possible to indicate the likelihood of the realized value of a variable falling within stated limits—typically described by the fluctuations around the average of a probability calculus.[33] On the other hand, in situations of uncertainty, the fluctuations of a variable are such that they cannot be described by a probability calculus (ADB 2002, p. 10).

The IPCC (2012) report defines uncertainty as

> [a]n expression of the degree to which a value or relationship is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty may originate from many sources, such as quantifiable errors in the data, ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty

[33] Note that in its Fifth Assessment Report, the IPCC defines risk differently: "Risk is often represented as the probability of occurrence of hazardous events or trends multiplied by the magnitude of the consequences if these events occur." In most instances, the IPCC definition refers to the calculation of expected damages or expected losses (resulting from hazardous events), and not of risk.

> can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgment of a team of experts" (IPCC 2012, p. 564).

The presence of uncertainty about climate change does not invalidate the conduct of the economic analysis of an investment project nor does it require a new type of economic analysis. While better and more accurate information may be desirable (ignoring the cost of producing such information), the conduct of economic analysis of investment projects and of their climate proofing does not require accurate and precise climate projections. However, it does require a different type of decision-making process in which the outcome of the economic analysis may not necessarily be simplified as a single NPV value but instead provide a range of NPVs across multiple climate change projections.[34]

This section begins with a discussion of the "traditional" approaches generally used to account for the presence of uncertainty or risk. These include sensitivity analysis and probabilistic (or risk) analysis. Alternative approaches to decision making are then discussed, including scenario analysis, real option analysis, and robust decision-making analysis.

At the outset, it must be noted that these decision-making approaches do not aim to resolve or eliminate uncertainty from the analysis, but to facilitate decision making in a context of uncertainty. Furthermore, these approaches do not aim to substitute for the economic analysis, but to use the outcome of the economic analysis (among other decision criteria) in ways that differ from selecting the option that maximizes NPV or expected NPV.

The overall message is that uncertainty about future climate should not be interpreted as a barrier to assessing the desirability of climate proofing investment projects.

Sensitivity Analysis

In the presence of "the unknown," the most widely used approach in economic analyses is sensitivity analysis (or sensitivity testing). Most (if not all) economic analyses of investment projects include such analysis. It is in the context of sensitivity testing that switching values are often computed, where a switching value is the value of a specific variable that makes the net present value switch from positive to negative, or conversely.

ADB (1997) describes the conduct of sensitivity analysis in the following way:

> Sensitivity analysis is a simple technique to assess the effects of adverse changes on a project. It involves changing the value of one or more selected variables and calculating the resulting change in NPV and IRR. Changes in variables can be assessed one at a time to identify the key variables. Possible combinations can also be assessed. Sensitivity analysis should be applied to project items that are numerically large or for which there is considerable uncertainty.

[34] As noted in World Bank (2010b), "the real challenge for the economic valuation of adaptation goes beyond uncertainty surrounding which climate change scenario is likely. [The challenge] has more to do with the absence of systematic approach to explicitly make informed decisions under uncertainty."

> The results of the sensitivity analysis should be summarized, where possible, in a sensitivity indicator and in a switching value. A sensitivity indicator compares the percentage change in a variable with the percentage change in a measure of project worth. The preferred measure is the expected NPV. A switching value identifies the percentage change in a variable for the expected NPV to become zero.

All economic analyses of ADB-financed investment projects follow the approach described above. As noted earlier, the typical economic analysis of projects financed by the World Bank includes sensitivity analysis by simply varying aggregate costs and benefits by some percentage (Box 1).

In the context of conducting the cost–benefit analysis of a climate-proofing option, sensitivity analysis essentially (and simply) involves changing the value of one or more variables that affect the costs or benefits of the climate-proofing option(s). If and when climate change is a key source of uncertainty or concern, sensitivity analysis should test the sensitivity of the project's NPV and of climate-proofing options to variations in key but uncertain climate parameters.

Switching values can also be calculated to indicate which value of a specific cost or benefit parameter makes the NPV of climate proofing equal to the NPV of not climate proofing an investment project (as exemplified in Box 4), or which value of a specific cost or benefit makes the net present value of alternative climate-proofing measures equal (as exemplified in Box 9).

The purpose of such sensitivity testing is to raise the level of confidence one has in recommending the adoption of the project with or without climate-proofing measures.

Key advantages of sensitivity testing are that it is extremely easy to conduct and it is useful to inform project design and identify potential mitigation measures in specific project areas. As a result, its use has become widespread.[35] However, its simplicity is also the source of a number of severe limitations, including the following:

- Sensitivity testing is often perceived as being subjective in that there is no specific reason justifying the direction (smaller or larger) or the extent to which the value of a specific variable may be assumed to change.
- As noted in ADB (2002), the use of standard percentages for variations (changes of plus or minus 10% or 20% are routinely applied—see Appendix 3) in sensitivity testing captures quite differential extents of likely variability. An impression of homogeneous variability is given, which is not warranted by reality.
- More importantly, sensitivity testing does not take into account the likelihood that the value of any specific variable may differ from the value originally estimated. As a result of this serious limitation, while sensitivity analysis allows computing a range of net present values within which the actual net present value of the adaptation option may fall, it prevents the computation of the *expected* net present value of the adaptation option. This shortcoming explains the use of a probabilistic approach to risk analysis.

[35] Appendix 3 presents a summary of the sensitivity analysis in the 34 lending projects approved by ADB between 1 January and 31 August, 2014.

With respect to the conduct of sensitivity analysis, ADB (2002) concludes that "its dependence upon judgment rather than empirical evidence and its modeling of uncertainty rather than risk (plus its inability to offer any decision rules following the presentation of its results) mean that its usefulness as a technique is ultimately limited."

The above shortcomings are particularly significant in a context of climate change as the sensitivity analysis may then fail to establish any causal relationship between climate change projections and the sensitivity of the costs and benefits to those changes.

A limited number of studies have suggested that the cost of climate proofing could add 5% to 20% to the capital cost of climate-sensitive investments (or to the climate-sensitive components of investment projects). In a recent review of the practice of climate risk and vulnerability assessment in 11 transport sector projects, it was found that the cost of climate proofing ranged between 0.5% and 8.7% of capital cost.

Table 3: Estimated Costs of Climate Proofing Investment Projects in the Transport Sector

Project Name	Cost of Adaptation
Main Roads and Bridges	
Bhutan: South Asia Subregional Economic Cooperation Road Connectivity Project (Project No. 39225-034; March 2014)	$1.6 million, or 5.2% of total project cost
Viet Nam: Central Mekong Delta Region Connectivity Project (Project No. 40255-033; July 2013)	$4.5 million, or 0.5% of total project cost
Papua New Guinea Bridge Replacement for Improved Rural Access Project (Project No. 43200-024; September 2011)	No estimate
Uzbekistan: Central Asia Regional Economic Cooperation Corridor 2 Road Investment Program (Project No. 42107-003; April 2010)	The adaptation measure costs $65,000 less than traditional approach.
Remote Rural Roads	
Inner Mongolia Road Development Project (Project No. 43029-013; September 2013)	No estimate
Cambodia Rural Roads Improvement Project (Project No. 42334-013; August 2010)	$5.4 million, or 8.3% oftotal project cost
Solomon Islands Second Road Improvement Project (Project No. 43381-012; October 2009)	$2.1 million, or 8.7% of total project cost
Timor-Leste Road Network Development Sector Project (Project No. 46260; August 2013)	No estimate
Urban Transport	
Viet Nam: Ho Chi Minh City Rapid Transit Line 2 Investment Program (Project No. 45200-002; January 2014)	$8.0 million, or 0.5% of total project cost
Waterways and Ports	
Anhui Intermodal Sustainable Transport Project (Project No. 45012-002; January 2014)	No estimate
Cook Islands AvatiuPort Development Project (Project No. 40287-023; November 2008)	$0.8 million, or 4.4% of total project cost

Source: ADB. 2014. *Climate Proofing ADB Investment in the Transport Sector: Initial Experience*. Manila.

However, studies have noted that these numbers are at best rough guesses of the climate proofing cost (Agrawala and Fankhauser 2008 and Fankhauser and Soare 2012). Climate-proofing measures and costs differ greatly from sector to sector, from location to location, and from project design to project design. As such, existing experience with climate proofing investment projects does not support broad and generic recommendations pertaining to the incremental capital cost of climate-proofing measures, such as indiscriminately applying a 10% increment to capital cost to account for climate proofing.

Probabilistic (or Quantitative) Risk Analysis

Conducting a "probabilistic or quantitative cost–benefit analysis" involves attaching probabilities to a series of possible outcomes, or attaching a probability distribution for the possible value of any given specific cost or benefit component of the project, instead of attaching a single deterministic value. Such probability distributions may be constructed using records of historical data. In such circumstances, the economic analysis provides an estimate of the expected economic efficiency of the investment project with a measure of its *expected* net present value. As noted in ADB (2002):

> Quantitative risk analysis associates a probability of occurring with different values of key variables. When such variables are varied simultaneously through a random selection of outcomes, a frequency distribution for the expected NPV can be produced showing the probability that the project is not acceptable. Decision makers will compare the scale of net benefits from different projects with their riskiness in selecting an individual project or a portfolio of projects.

The use of a probabilistic approach to assess the impacts of climate change on investment projects is not unusual and its conduct remains relatively simple.[36]

The absence of a set of probabilities over climate change projections does not imply that probabilities cannot be used in assessing the economic viability of climate-proofing options. A set of *subjective* probabilities may be used based on the outcome of general circulation models. However, it is important to note that such probabilities must be based on a subjective assessment of climate change projections, and are not themselves the outcome of the downscaling of general circulation models.

Probabilistic (or risk) analysis allows selecting multiple variables, which can all be varied simultaneously according to the specific probability distribution attached to each variable. This process, known as a Monte Carlo simulation analysis, proceeds as follows: a specific value of each individual variable (cost component or benefit component) is generated randomly according to the specific probability distribution attached to each variable. For any given draw of specific values, the net present value of the investment project with and without climate-proofing measures can be calculated under various climate projections (Box 13). This process, by means of computer, is then repeated many thousands of times.

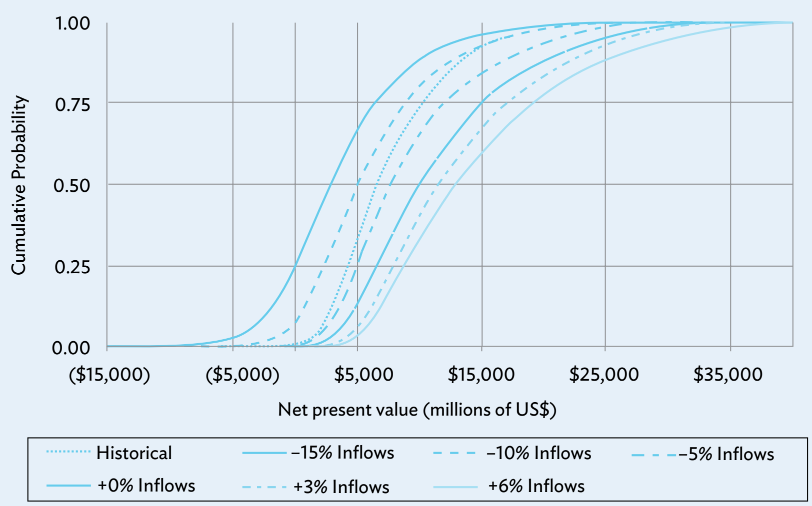
[36] See, for example, Eijgenraam et al. (2012) for an application of a probabilistic analysis to assessing the optimal timing of climate-proofing options. Additional applications of a probabilistic approach are provided by Purvis et al. (2008), and Foti et al. (2014).

ADB (2002) provides comprehensive details of the conduct of probabilistic risk analysis including the conduct of Monte Carlo simulation.[37]

The outcome of the analysis is a probability distribution of net present values. This probability distribution allows the computation of an "expected" (mean) net present value of the adaptation option under consideration instead of solely a given net present value or range of net present values. The same probability distribution also allows computing the probability that the net present value of the adaptation option will be negative. While risk-neutral decision makers would show interest in the computed mean net present value, risk-averse decision makers will also show concern over the nature of the circumstances that generate a negative net present value.

Box 13: Investing in a Hydropower Project: Climate Change and Monte Carlo Simulation

In a recent study, Jeuland (2010) conducted a cost–benefit analysis of a hydropower scheme on the Blue Nile river in Ethiopia. Of the 34 parameters included in the analysis (including 6 model parameters, 13 cost components, and 10 benefit components), uniform and triangular probability density functions are defined for 23 of these components. A random draw is performed from each of the specified distributions and for each draw, a net present value is calculated. In this study, 10,000 Monte Carlo trials were performed to map NPV probability distribution. The cumulative probability distribution with and without climate change is presented below. The dashed yellow line represents cumulative distribution of NPVs without climate change. The expected NPV is positive and very few realizations show a negative NPV. The project's NPV increases with positive changes in water inflows, and decreases with negative changes in water inflows. For larger reductions in water inflows, there is an increasing probability that the project's NPV is negative. With a reduction of 15% in inflows, there is a 25% likelihood that the NPV of the project is negative.



Source: Jeuland, M. 2010. Economic implications of climate change for infrastructure planning in transboundary water systems: an example from the Blue Nile. *Water Resources Research*. 46.

[37] Additional references include Kroese et al. (2011), Robert and Casella (2004), and Rubinstein and Kroese (2007).

The conduct of probabilistic (or risk) analysis would be demanding if performed manually. However, packaged software allows the conduct of Monte Carlo simulation analysis in a relatively simple way.[38]

Beyond the "traditional" approaches presented above, a large number of documents discuss decision making under uncertainty (see ADB's guidelines among others), and an increasing number focus specifically on climate change uncertainty.[39] It is not a purpose of this report to provide a detailed review of approaches for decision making under uncertainty. Nonetheless, given the nature of the challenges presented by uncertain climate change, two approaches are briefly presented below which may address these challenges. Note that these represent approaches to decision-making processes into which the outcome of the economic analysis, where available, may serve as input to guide or facilitate decision-making. These approaches do not serve as substitute to the economic analysis.

Scenario Analysis

The abundance of climate change projections[40] and the impossibility of identifying which of these projections may be more or less likely represent uncertainty, not risk. Sources of uncertainty on future climate conditions abound ranging from uncertainty about anthropogenic and non-anthropogenic greenhouse gas emissions, uncertainty about future greenhouse atmospheric concentration (which must account for the future role of carbon sinks), and uncertainty arising from general circulation models (GCMs) and the downscaling to regional and local levels of GCM projections. Wilby and Dessai (2010) refers to a "cascade" of uncertainty to illustrate the growth in the range of uncertainty as one moves closer to assessing the impacts of climate change at a local level. Given the nature of these sources, uncertainty will not disappear (see Curry 2011 and Refsgaard et al. 2013 for a more detailed discussion of climate change uncertainty). Dessai et al. (2009) argue that "the accuracy of climate predictions is limited by fundamental, irreducible uncertainty."

The presence of uncertainty as to the nature of future climate conditions does not invalidate the conduct of cost–benefit analysis. In principle, for any given climate projection provided by any given climate model, a project's NPV with climate change can be estimated, and the economic viability of technically feasible climate-proofing measures can be assessed following the concepts and principles presented in Part B. In principle, one could estimate as many project NPVs both with and without climate-proofing measures for as many climate projections as there are available.

---

38 Without endorsing these packages, two widely used software programs are @RISK (built as an Excel template) and Crystal Ball.

39 Among others, see Hallegatte (2009), Ranger et al. (2010), Markandya (2014), and Willows and Connell (2003). Nassopoulos et al. (2012) present a case study of an optimal dam design using the cost–benefit analysis framework in the presence of an uncertain climate change.

40 For example, 20 general circulation models downscaled to the project level under four representative concentration pathways would yield 80 climate projections for selected climate variables such as temperature and precipitation.

For the purpose of illustration, consider a hydropower investment project with an estimated positive NPV in the absence of climate change. In Figure 8,[41] climate change projections pertaining to changes in precipitation (deviation from historical mean, first panel) are transformed into estimated changes in water availability using hydrological model(s) (second panel). These changes can then be mapped into changes in hydropower production for the designed hydropower scheme (third panel). The impact of changes in power production can then be mapped into gains or losses in economic benefits or costs and a revised NPV can be calculated (fourth panel). In Figure 8, the NVP of the hydropower investment project is estimated to become negative for significant reductions in precipitation while the NPV slightly increases with positive changes in precipitation. The need for identifying and analyzing the technical feasibility and economic viability of climate-proofing measures would particularly arise in circumstances where the NPV is estimated to be negative. Alternatively, for the purpose of the example, assume that the NPV presented in Figure 8 is the NPV of the project with climate-proofing measures. This would indicate that under GCM1, GCM2, and GCM3, the project should be abandoned; under GCM4 and GCM5, one is indifferent to proceeding or not with the project; while under all other scenarios, the recommendation would be to proceed with the project. Equipped with this (and other) information, decision makers must then determine whether to proceed with the project.

Consider an additional example in which the NPV of an agriculture or irrigation expansion project has been estimated to be positive when not accounting for climate change. Climate change projections pertaining to temperature and precipitation for a suitable time frame across a number of models and scenarios are presented in Figure 9.[42] Well over 100 such projections have been provided in this example. Given weather conditions in the project area, agriculture experts have determined that increases in temperature and decreases in precipitation would adversely impact productivity, while increases in precipitation would increase productivity.

While in principle the impact of climate change on the costs and benefits of the project could be estimated for each combination of projections of temperature and precipitation change, the multiplicity of these may overwhelm time and resources available for the analysis. In Figure 9, it is noted that less than 10% of estimates project precipitation changes of less than 11.5% or more than approximately 14.5%. Similarly, less than 10% of estimates project temperature changes of less than 0.85°C or more than 2.85°C. Estimates within the red square represent most combinations of projections. The four encircled projections at the corners of the square in effect bracket the 10%–90% exceedance values for both temperature change (°C) and precipitation change (%). Given the information provided by agriculture experts, the projection in the upper left corner would represent an approximate worst-case scenario (lowest NPV) and the projection in the lower right corner an approximate best case scenario (highest NPV) within the set of projections contained in the square. The NPV of the project for all combinations of projections within the red square would fall within those two NPVs. Such an approach limits the extent of the analysis to be performed.

---

[41] While presented solely for purpose of illustration, the numbers presented in Figure 7 are based on an actual hydropower investment project.

[42] Brekke et al. (2009) provides the basis for Figure 9.

Figure 8: From Climate Projections to Net Present Value

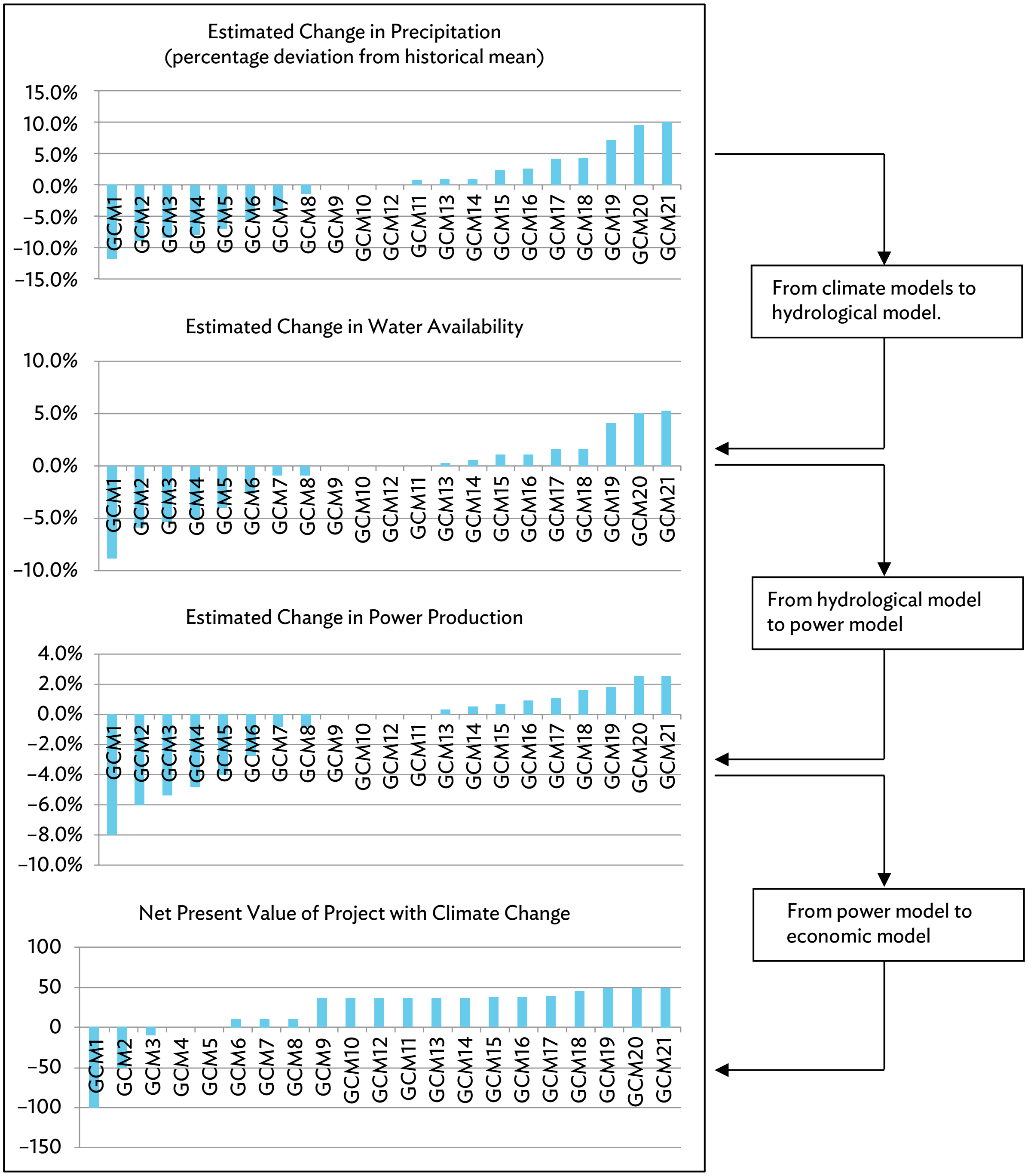
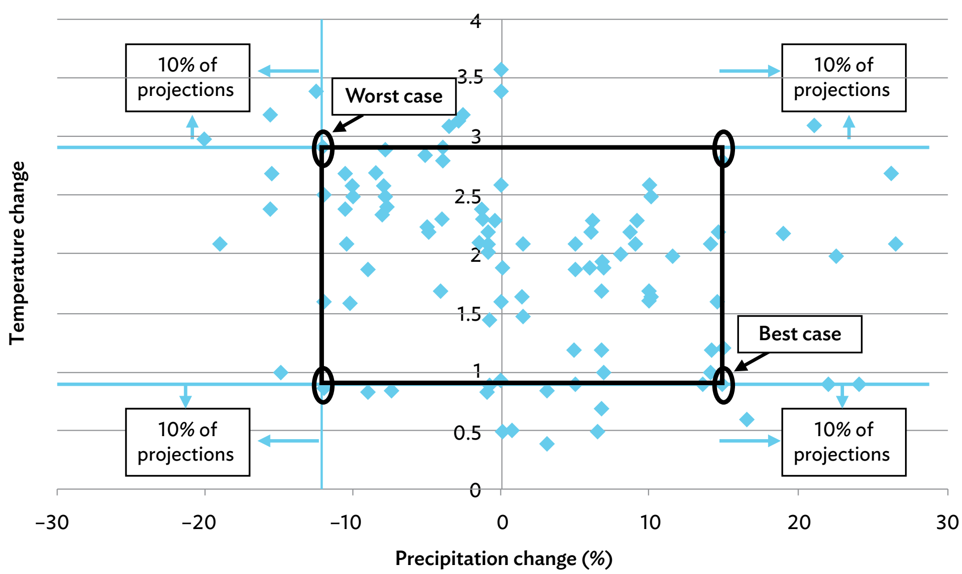


Figure 9: Projected Changes in Temperature and Precipitation



The presence of uncertainty implies that the decision-making process could not solely be based on selecting the climate-proofing approach that maximizes a project NPV: as illustrated in Figure 8, the NPV of the project with climate change will vary across climate projections, as will the costs and benefits (and potentially the nature) of the climate-proofing measures. The absence of a set of probabilities over climate change projections implies the impossibility of calculating an *expected* net present value. In particular, in the context of Figure 8, computing an average (mean) change in precipitation across the 21 precipitation changes amounts to assuming that each of the 21 projected changes is equally likely, or in other words, that a uniform probability distribution applies over the set of projections. Though regularly performed, such computation of an average climate change projection is technically incorrect. Similarly, the nature of climate change projections does not support the selection of a single "best guess" projection.

Real Option Analysis[43]

From an economic point of view, not only is the level of climate proofing of investments important (how much climate proofing to invest in), but the timing of that investment is of similar importance. Factors impacting the decision to climate proof early or to wait include the following:

- The costs of climate proofing (measured in real terms) always favor waiting: the longer the wait, the smaller the cost of climate-proofing in present value terms.
- Early climate proofing may be justified if there are immediate benefits to climate proofing, which may arise in the following two situations: (i) the net benefits of the investment project are highly sensitive to current climate variability and climate risk and not solely to future projected climate conditions, and (ii) there are strong cobenefits or ancillary benefits to climate proofing investments.
- Early climate proofing may also be justified if there is no flexibility (or some irreversibility features) to modify infrastructure design to respond to changes in climate conditions observed in the future (for example, it may not be possible to raise a bridge platform once constructed). Conversely, delaying climate proofing may be of greater interest with the presence of such flexibility.
- More or better information is expected in the future that may support a review of climate-proofing decisions.

From an economic point of view, the decision to undertake "anticipatory" or "reactive" climate proofing of investments would simply be guided by assessing the net present value of the investment under both approaches and of selecting the option that yields the largest net present value.

The purpose of a real options analysis is to allow evaluating the benefits of delaying climate proofing investments or the benefits of incorporating flexibility in project design so as to allow climate proofing at a later point in time if and when deemed desirable.

In a number of circumstances, especially when climate proofing takes the form of adding equipment, expanding facilities, or retrofitting infrastructure, issues will pertain not only to whether to climate proof but also as to when to undertake climate proofing.

All other things being equal, the following factors should be considered:

- The cost of climate proofing will always favor waiting as long as possible before undertaking such investment. The higher the cost of implementing the climate-proofing measure, the longer the desirable waiting time.

[43] Examples of the application of real option analysis in the context of climate change include Jeuland and Whittington (2013), Steinschneider and Brown (2012), and Dobes (2010). The literature on climate change adaptation occasionally refers to the timing of adaptation as "anticipatory" adaptation (which occurs before climate change is observed) and "reactive" adaptation (which occurs after climate change is observed). Similar concepts of anticipatory and reactive actions apply to climate proofing investments (Refsgaard et al. 2013).

- If climate proofing responds to existing climate variability and not solely to projected changes in the future, or if climate proofing provides large ancillary benefits, it may then be justified to undertake climate proofing of investments earlier rather than later. The larger the ancillary benefits, the shorter the desirable waiting time.
- The larger (smaller) the damages resulting from projected climate change, the earlier (later) the climate-proofing investment will be.
- The larger (smaller) the residual damages, the later (earlier) the climate-proofing investment will be.[44]

The economic analysis of climate proofing investment projects can provide guidance as to the optimal timing to implement a climate-proofing measure. Given any stream of annual benefits associated with climate proofing and any capital cost associated with the implementation of the climate-proofing measure itself, it is possible to determine the time (year) of implementation that will maximize the measure's NPV (Box 14).

Box 14: Example 6: Optimal Timing of Implementation of a Climate-Proofing Measure

For the purpose of illustration, consider the following example. The investment project is a thermal power plant. Once approved, the project will take 3 years to implement and will start delivering benefits in Year 4. The expected project lifetime ends in Year 25. As a result of climate change, the project is deemed vulnerable to increasing temperatures of ambient air and surface water, which may hamper the efficiency of the plant—surface water temperatures above design standards could even force shutdowns.

A climate-proofing measure has been identified as technically feasible (for example, putting in place a second cooling tower). The cost of the climate-proofing measure is estimated to be $25 million and the investment can be completed in 1 year. The expected benefits of the climate-proofing measure are nil until the power plant initiates production in Year 4. Expected benefits in Year 4 are estimated to be $2.0 million and to increase at a rate of 10% per year until they reach $3.45 million in Year 7 and stabilize at this level until the end of the project's lifetime in Year 25.

The issue being faced by decision makers pertains to the "best" timing of the investment, which in economic terms is interpreted as the timing of the investment that maximizes the net present value of the climate-proofing investment. While the climate-proofing measure could be put in place in years 1 or 2, it is apparent that it would not be economically efficient to do so as such investment would provide no benefits until Year 4. With the help of a spreadsheet, it is simple to calculate the investment's net present value assuming the investment takes place in years 1, or 2, or 3, or until Year 25. (It should also be apparent that if undertaken toward the end of the project, the net present value of such investment would be negative as the time horizon over which the investment delivers benefits becomes shorter).

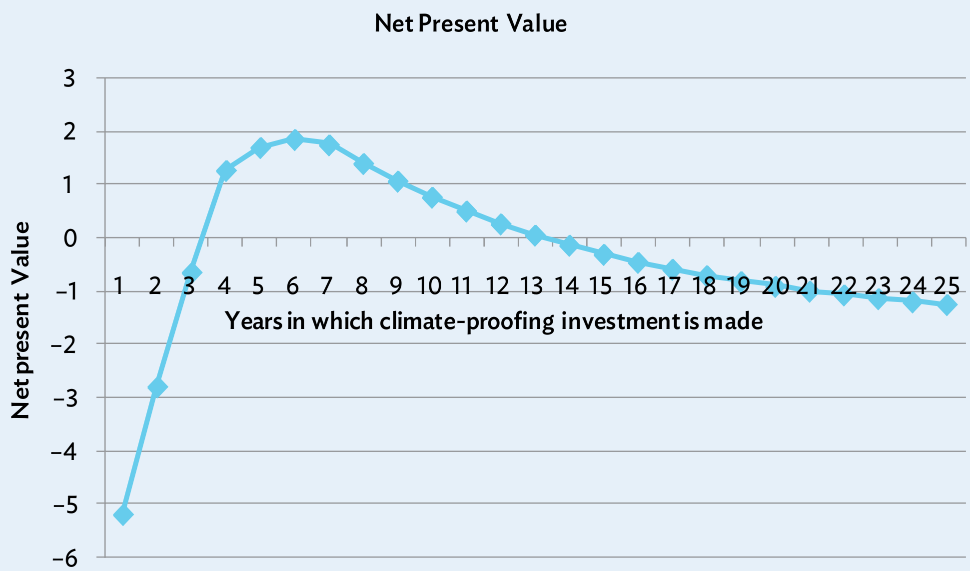
continued on next page

[44] Wright et al. (2003) provides a more detailed discussion.

Box 14: continued

The computation of such net present value (assuming a 12% discount rate) delivers the curve presented in the figure below. Given the assumptions and numbers presented above, economic efficiency would dictate in the case of this example that the net present value of this climate-proofing investment is maximized if the measure is implemented in Year 6 of the project.

While much stylized, this simple example illustrates that the economic analysis of investing in climate-proofing measures can be used not only to determine whether to invest in climate proofing, but also to identify the optimal timing of such investment.



Similarly, the physical properties of a project's infrastructure may be designed to allow or preserve flexibility in the future for climate proofing. Examples of application of real options analysis are numerous (Box 15).

While preserving flexibility can be costly, it has two important benefits. First, it avoids large climate-proofing investments at the time of project implementation which, upon actual realization of climate conditions, may not have been warranted (over-adaptation). Second, it may avoid more costly climate-proofing investments in the future since the infrastructure is "ready" for climate proofing. The economic analysis can shed light on the nature of the climate-proofing measures and the implementation timing that will maximize economic efficiency.

Box 15: Real Option

The examples below were initially described in Box 3.

Khulna Water Supply Project (Bangladesh). The climate risk and vulnerability assessment found that projected decreases in river flows in the dry season and sea level rise would increase the salinity of the river, a main source of water supply. There is, however, considerable uncertainty as to the rate at which salinity is expected to increase and impair water supply. Two adaptation options were proposed: shifting the water intake point further upstream by 4 km or increasing the size of the impounding reservoir by 12 million cubic meters. A further detailed analysis was conducted to determine the required size of the impounding reservoir. Given the extent of the uncertainty pertaining to the rate of salinization, the city has planned to gradually increase the size of the impounding reservoir while continuing to monitor the salinity levels in the river instead of undertaking a large investment at the time of project implementation. However, for the purpose of implementing this climate-proofing option, the project immediately secured property rights over additional land that can be used to increase the size of the impounding reservoir if indeed this proves necessary in the future (see ADB 2011b for details).

Avatiu Port Development Project (Cook Islands). The $24.6 million project will rehabilitate and expand the capacity of Avatiu Port in the Cook Islands. Out of the $24.6 million, $800,000 was earmarked to modify project design so as to allow for future adaptation to the anticipated impact of sea level rise. The revised design involves the strengthening of pilings to provide the load bearing capacity needed to raise the wharf edge level by up to 0.5 meters if there were a need to do so in the future. This method has been selected for economic efficiency and set the wharf edge level to an elevation that is more appropriate for current conditions and the larger ships using the port (see ADB 2014c for more details).

Robust Adaptation to Climate Change

A number of authors have pointed out the inherent difficulty associated with undertaking impact and vulnerability assessments given the degree of uncertainty associated with climate change. A key issue pertains to the efficacy of general circulation models for climate-proofing analysis. Kundzewicz and Stakhiv (2010) have noted that general circulation models still cannot reconstruct many important details of climate at smaller scales.

On the other hand, quantified climate projections do provide information that may be of interest to project designers and sector planners in some locations and for some climate variables (for example, it is well known that there are smaller differences across models pertaining to temperature projections than there are for precipitation projections; in particular, all models agree on the sign of temperature change). As pointed out by Kundzewicz and Stakhiv (2010), “reliance on stochastics alone … would be tantamount to incomplete use of available information” (p. 1088).

Wilby and Dessai (2010) point out that "*characterizing* uncertainty through concerted scientific action may be a tractable proposition, but there appears to be no immediate prospect of *reducing* uncertainty in the risk information supplied to decision makers" (p. 1092). The literature certainly contains important warnings pertaining to the use of climate projections obtained from the downscaling of general circulation models (Barsugli et al. 2009).

As an alternative to the top-down approach of first asking what climate change may entail in the future and of then assessing the possible impacts of various climate projections on the project's performance, a different approach lies in first identifying the extent of climate change that the project can cope with before its performance is adversely impacted and then assessing when (e.g., if vulnerability pertains to sea level rise) or how often (e.g., if vulnerability pertains to peak wind or peak water discharges) these adverse conditions may be met.

As a result, a number of authors refer to the concept of *robust adaptation* to climate change (Box 16). A detailed applied demonstration of the approach is available in Lempert et al. (2013) in the context of flood risk management in Ho Chi Minh City.

Box 16: Robust Adaptation to Climate Change

Wilby and Fowler (2010) note that "the sheer scale of the uncertainty to be sampled (but never entirely quantified) by hypermatrix experiments shows the fallacy of scenario-led adaptation, and sets the scene for an adaptation paradigm based on robustness, flexibility, monitoring, and review."

Robust adaptation measures are defined as measures that (i) satisfy a number of "robustness principles" such as low-regret, reversible, and flexible (to minimize the cost of being wrong about future climate change); (ii) incorporate safety or security margins into design criteria; and (iii) employ "soft" (e.g., institutional and planning) solutions (Hallegatte 2009).

The search for robust adaptation measures has been characterized as follows (Wilby and Dessai 2010):

Step 1: Construct an inventory of all adaptation options for the most significant risks caused by climate change.

Step 2: Through a process of screening and appraisal, identify "preferred" adaptation options that would reduce vulnerability under the present climate regime.

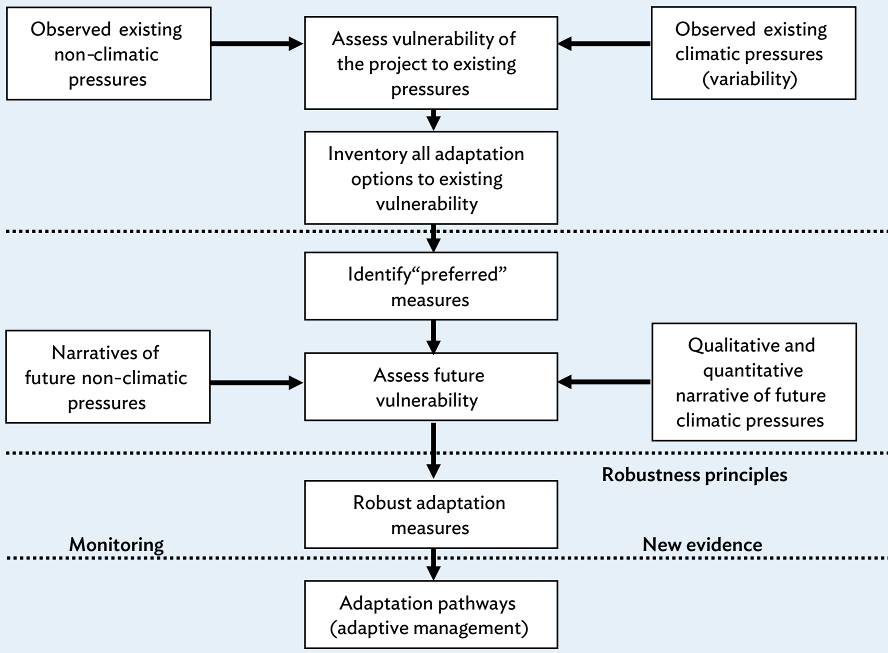
Step 3: Describe quantitatively and qualitatively plausible changes in climate and non-climate variables to identify future vulnerability.

Step 4: Among the set of "preferred" adaptation options (Step 2), identify those measures that are robust to future vulnerability.

Step 5: Establish an "adaptation" pathway that will be shaped by a careful monitoring of the changing climate and environmental conditions, the scientific evidence, and society's attitudes to climate risk (adaptive management).

continued on next page

Box 16: continued



Source: Adapted from Wilby, R.L. and S. Dessai. 2010. Robust adaptation to climate change. *Weather*. 65(7). 180–185.

In the context of this report, it is of interest to note that the concept of robust adaptation to climate change does not rule out the use of economic analysis. As noted in Lempert et al. (2013), "an analyst using a simple spreadsheet model to compare the cost–benefit ratios of alternative investments could use [robust decision making] to run the spreadsheet over many thousands of combinations of assumptions and to identify those futures where one investment was consistently more cost-effective than another."

Economic Analysis Guiding Decision Making

The outcome of the economic analysis of climate-proofing options may guide decision making in three different directions.

As a result of the outcome of the climate risk and vulnerability assessment, decision makers may elect to invest in climate-proofing measure(s) at the time the project is being designed (climate proof now).

Such a decision may result in circumstances where any of the following applies:

- The costs of climate proofing now are estimated to be relatively small while the benefits (the avoided expected costs from not climate proofing), even though realized only under future climate change, are estimated to be very large. This is occasionally referred as a *low-regret* approach.

- The costs of climate proofing at a later point in time are expected to be prohibitive (as a result of a lack of flexibility) or climate proofing at a later point in time is technically not possible.
- Among the set of climate-proofing options, one or more options deliver net positive economic benefits regardless of the nature and extent of climate change. Such options are occasionally referred as *no-regret* climate-proofing options.
- The set of climate-proofing options includes at least one option that not only reduces climate risks to the project, but also has other social, environmental, or economic benefits. Such options are occasionally referred as *win-win* climate-proofing options.

Alternatively, decision makers may elect to invest minimally at the time of project design and implementation and to take steps to ensure that the project can be climate proofed in the future if and when circumstances indicate climate proofing to be a better option than not climate proofing. This type of decision aims to ensure that the project is "ready"for climate proofing if and when required. As such, the concept of *climate readiness* is occasionally referred to in this situation. This concept is akin to the *real options* approach to risk management. It involves avoiding the foreclosure of climate-proofing measures and preserving flexibility to improve climate resilience as climate change is actually observed (as opposed to projected to change).

For example, while current sea level rise and storm surge scenarios may not warrant the construction today of sea dikes suitable to projected higher sea level and stronger storm surges in a distant future, the base of the sea dike may nonetheless be built large enough today to accommodate a heightening of the sea dike at a later point in time. A decision of this nature was made in the context of the Cook Islands Avatiu Port Development Project.

Finally, decision makers may elect to make no changes and no incremental investment at the time of project design and implementation, to await further information on climate changes and their impacts on the infrastructure assets, and to invest in climate proofing if and when needed in the future.

This type of decision may result under one or more of the following circumstances:

- The costs of climate proofing now are estimated to be large relative to the expected benefits.
- The costs (in present value terms) of climate proofing (e.g., retrofitting) at a later time are expected to be no larger than climate proofing now.
- The expected benefits of climate proofing are estimated to be relatively small.

The last two types of decisions are akin to an adaptive management approach, which consists of monitoring changes in climate and putting in place climate-proofing measures over the project's lifetime as changes and their impacts are observed. Key to both types of decisions is to ensure that appropriate data and information are collected.

Conclusions

The basic purpose of undertaking the cost–benefit analysis of an investment project is to provide information to decision makers as to the contribution of the project to society's welfare. The analysis provides a means to systematically identify, quantify, and wherever possible value all impacts of the project, including (where relevant) its environmental impacts, even in circumstances where these impacts occur over long time horizons.

The role of the economic analysis is to support decision making as it provides information pertaining to the economic efficiency of investment projects, including the economic efficiency of climate proofing investment projects. The economic analysis is not a substitute but an input to decision making.

Two important messages with respect to the economics of climate proofing investment projects have been provided in this report.

First, a project's economic analysis does not, cannot, and has never provided estimates of a project's costs and benefits and of the resulting net present value with certainty. It can only provide a possible range of a project's net present value within which the true (and unknown) net present value may fall within a reasonable degree of confidence. Certainty is beyond the realm of any economic analysis. This certainly applies to the economic analysis of climate-proofing measures.

Second and perhaps more importantly, the presence of uncertainty about climate change projections does not invalidate the conduct or the outcome of the economic analysis of investment projects in a context of climate change. However, this uncertainty needs to be explicitly recognized, and the project preparation team, in consultation and dialogue with national stakeholders, need to have in hand all the information needed for decision-making purposes. The role of the economic analysis is to guide and support this process.

As stated earlier, the outcome of the economic analysis provides information as to the economic efficiency of investing in climate-proofing options.

While this report focuses on the economic analysis of climate-proofing options, it is recognized (perhaps especially in a context of uncertainty) that decisions as to whether to go ahead with an investment project (or, similarly, as to whether to climate proof an investment project) may be based on criteria not strictly limited to economic efficiency (USAID 2007).[45]

As noted in ECA (2009):

> As with all cost–benefit analysis, the analytical results ...are intended to start a discussion—they will not provide an explicit answer on what the most effective portfolio of adaptation measures would be for a particular location. The measures that are prioritized in such a portfolio will not necessarily be only the most cost-effective ones .... Rather, a broader set of selection criteria—covering both evaluation and implementation—will be needed, including measures' potential for impact, their ease of implementation, their synergies, as well as their coverage of both low- and high-frequency hazards.

It is hoped that this report will facilitate a greater understanding of the conduct of the economic analysis of climate proofing investment projects in the context of a climate risk and vulnerability assessment. ADB is committed to continue the development of technical resources and document best practices to assist both its own operational staff and officials of DMC partners to manage climate-related risks and vulnerability throughout the project cycle.

[45] This report does not address or describe the use and the conduct of multi-criteria analysis. See Janssen and Herwijnen (2006), and Watkiss and Hunt (2013) for a more detailed discussion of multi-criteria analysis. The *Journal of Multi-Criteria Decision Analysis* presents theoretical developments and practical applications of the analytical approach. The method has been applied to address numerous climate change adaptation issues.

References

Adger, W.N. et al. 2005. Successful adaptation to climate change across scales. *Global Environmental Change*. 15. 77–86.

Agrawala, S. and S. Fankhauser. 2008. *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments*. Paris: Organisation for Economic Co-operation and Development.

Arrow, K.J. et al. 2012. *How Should Benefits and Costs Be Discounted in an Intergenerational Context? The Views of an Expert Panel*. Resources for the Future, Working Paper 12-53. Washington, DC: Resources for the Future.

Asian Development Bank (ADB). 1997. *Guidelines for the Economic Analysis of Projects*. Manila.

———. 2002. *Handbook for Integrating Risk Analysis in the Economic Analysis of Projects*, Manila.

———. 2003. *Operations Manual*. Manila.

———. 2005. *Climate Proofing: A Risk-Based Approach to Adaptation*. Manila.

———. 2008. *Strategy 2020:The Long-Term Strategic Framework of the Asian Development Bank 2008–2020*. Manila.

———. 2009. *The Economics of Climate Change in Southeast Asia: A Regional Review*. Manila.

———. 2010. *Addressing Climate Change in Asia and the Pacific: Priorities for Action*. Manila.

———. 2011a. *Guidelines for Climate Proofing Investments in the Transport Sector: Road Infrastructure Projects*. Manila.

———. 2011b. *Adapting to Climate Change: Strengthening the Climate Resilience of Water Sector Infrastructure in Khulna, Bangladesh*. Manila.

———. 2012a. *Guidelines for Climate Proofing Investments in Agriculture, Rural Development, and Food Security*. Manila.

———. 2012b. *Adaptation to Climate Change: The Case of a Combined Cycle Power Plant*. Manila.

———. 2013a. *Environment Operational Directions 2013–2020: Promoting Transition to Green Growth in Asia and the Pacific*. Manila.

———. 2013b. *The Economics of Climate Change in the Pacific*. Manila.

———. 2013c. *Key Areas of Economic Analysis of Investment Projects: An Overview*. Manila.

———. 2013d. *Guidelines for Climate Proofing Investments in the Energy Sector*. Manila.

———. 2013e. *Cost–Benefit Analysis for Development: A Practical Guide*. Manila.

———. 2014a. *Midterm Review of Strategy 2020: Meeting the Challenges of a Transforming Asia and the Pacific*. Manila.

———. 2014b. *Assessing the Cost of Climate Change and Adaptation in South Asia*. Manila.

———. 2014c. *Climate Proofing ADB Investment in the Transport Sector: Initial Experience*. Manila.

———. 2014d. *Central Mekong Delta Connectivity Project: Rapid Climate Change Threat and Vulnerability Assessment*. Manila.

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

Barsugli, J., C. Anderson, and J.B. Smith. 2009. *Options for Improving Climate Modeling to Assist Water Utility Planning for Climate Change*, Water Utility Climate Alliance.

Belli, P. et al. 1998. *Handbook on Economic Analysis of Investment Operations*. Operational Core Services Network, Learning and Leadership Center, The World Bank. Washington, DC: World Bank

Boardman, A. et al. 2010. *Cost–Benefit Analysis.* Prentice Hall. New Jersey.

Brekke, L.D. et al. 2009. *Climate Change and Water Resources Management—A Federal Perspective*. US Geological Survey Circular 1331.

Burgess, D.F. and R.O. Zerbe. 2011. Appropriate discounting for benefit-cost analysis. *Journal of Benefit-Cost Analysis*. 2.

Canadell, J.G. et al. 2007. Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences (USA)*. 104(47).18866–18870.

Chambwera, M. and J. Stage. 2010. *Climate Change Adaptation in Developing Countries: Issues and Perspectives for Economic Analysis.* International Institute for Environment and Development. London.

Commonwealth of Australia. 2006. *Handbook of Cost–Benefit Analysis*. Department of Finance. Canberra.

Cropper, M.L. 2012. *How Should Benefits and Costs Be Discounted in an Intergenerational Context?* Resources for the Future, Working Paper 12–42. Washington, DC: Resources for the Future.

Curry, J. 2011. Reasoning about climate uncertainty. *Climatic Change*. 108. 723–732.

DeConto, R.M. et al. 2012. Past extreme warming events linked to massive carbon release from thawing permafrost. *Nature*. 484. 87–91.

Dessai, S. et al. 2009. Climate prediction: a limit to adaptation? In W.N. Adger, ed. *Adapting to Climate Change: Thresholds, Values, Governance*. Cambridge: Cambridge University Press.

Dobes, L. 2010. *Notes on Applying "Real Options" to Climate Change Adaptation Measures, with Examples from Viet Nam*. Centre for Climate Economics and Policy, Research Report 75. Australian National University, Sydney.

Domingues, C.M. et al. 2008. Improved estimates of upper-ocean warming and multi-decadal sea-level rise. *Nature*. 453. 1090–1093.

Economics of Climate Adaptation Working Group (ECA). 2009. *Shaping Climate-Resilient Development: A Framework for Decision-Making.*

Eijgenraam, C. et al. 2012. *Flood Prevention by Optimal Dike Heightening*. Working Paper. Netherlands Bureau of Economic Policy Analysis.

Emanuel, K.A. 2013. Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century. *Proceedings of the National Academy of Sciences (USA)*. 110. 12219–12224.

European Commission. 2008. *Guide to Cost Benefit Analysis of Investment Projects.* Prepared for Evaluation Unit, DG Regional Policy, European Commission.

———. 2013. *Adaptation in Europe: Addressing Risks and Opportunities from Climate Change in the Context of Socio-Economic Developments*. EEA Report No. 3/2013. Copenhagen.

Fankhauser, S. and R. Soare. 2012. *Strategic Adaptation to Climate Change in Europe*. European Investment Bank, EIB Working Papers 2012/01.

Foti, R., J.A. Ramirez, and T.C. Brown. 2014. A probabilistic framework for assessing the vulnerability to climate variability and change: the case of the US water supply system. *Climatic Change*. 125(3–4). 413–427.

Gollier, C. 2012. *Pricing the Planet's Future: The Economics of Discounting in an Uncertain World*. Princeton and London: Princeton University Press.

Hallegatte, S. 2009. Strategies to adapt to an uncertain climate change. *Global Environmental Change*. 19. 240–247.

———. 2014. *Natural Disasters and Climate Change: An Economic Perspective*. Springer, Switzerland.

Hanna, E. et al. 2013. Ice-sheet mass balance and climate change. *Nature*. 498. 51–59.

H.M. Treasury. 2003. *The Green Book: Appraisal and Evaluation in Central Government*. London.

———. 2009. *Accounting for the Effects of Climate Change. Supplementary Green Book Guidance*. London.

Intergovernmental Panel on Climate Change (IPCC). 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change C.B. Field et al., eds. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

———. 2013. *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

———. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Janssen, R. and M. Herwijnen. 2006. A Toolbox for Multicriteria Decision-Making. *International Journal of Environmental Technology and Management*. 6(1). 20–39.

Jeuland, M. and D. Whittington. 2013. *Water Resources Planning under Climate Change: a Real Options Application to Investment Planning in the Blue Nile*. Environment for Development and Resources for the Future, EfD DP 13-05. Washington, DC.

Jones, et al. 2012. Harnessing nature to help people adapt to climate change. *Nature Climate Change*. 2. 504–509.

King, M.A. et al. 2012. Lower satellite-gravimetry estimates of Antarctic sea-level contribution. *Nature*. 491. 586–589.

Knutson, T.R., et al. 2010. Tropical cyclones and climate change. *Nature Geoscience*. 3. 157–163.

Kossin, J.P., K.A. Emanuel, and G.A.Vecchi. 2014. The poleward migration of the location of tropical cyclone maximum intensity. *Nature.* 509. 349–352.

Kroese, D.P., T. Taimre, and Z.I. Botev. 2011. *Handbook of Monte Carlo Methods*. New York: John Wiley & Sons. p. 772.

Kundzewicz, Z. W. and E.Z. Stakhiv. 2010. Are climate models "ready for prime time" in water resources management applications, or is more research needed? *Hydrological Sciences Journal*, 55, 1085–1089.

Lebegue, D. 2005. *Rapport Lebegue: Revision du Taux d'Actualisation des Investissements Publics*. Paris: Commissariat General au Plan.

Lempert, R. et al. 2013. *Ensuring Robust Flood Risk Management in Ho Chi Minh City*. Policy Research Working Paper 6465. Washington, DC: World Bank.

Levermann, A. et al. 2013. The multimillennial sea-level commitment of global warming. *Proceedings of the National Academy of Sciences (USA)*. 110. 13745–13750.

Lopez, A., L.A. Smith, and E. Suckling. 2011. *Pattern Scaled Climate Change Scenarios: Are These Useful for Adaptation?* Working paper, Grantham Research Institute on Climate Change and the Environment. London.

Markandya, A. 2014. Incorporating climate change into adaptation program and project appraisal. In A. Markandya, ed. *Routledge Handbook of the Economics of Climate Change Adaptation*. London and New York: Earthscan.

Meehl, G.A. et al. 2012. Relative outcomes of climate change mitigation related to global temperature versus sea-level rise. *Nature Climate Change.* 2. 576–580.

Milly, P.C.D. et al. 2008. Stationarity is dead: Whither water management? *Science.* 319. 573–574.

Moore, M.A. et al. 2013. More appropriate discounting: the rate of social time preference and the value of the social discount rate. *Journal of Benefit-Cost Analysis*. 4. 1–16.

Munang, R. et al. 2013. Climate Change and Ecosystem-Based Adaptation: A New Pragmatic Approach to Buffering Climate Change Impacts. *Current Opinion in Environmental Sustainability*. 5. 1–5.

Nassopoulos, H., P. Dumas, and S. Hallegatte. 2012. Adaptation to an uncertain climate change: cost benefit analysis and robust decision making for dam dimensioning. *Climatic Change*. 114. 497–508.

Nicholls, R.J. et al. 2006. *Metrics for Assessing the Economic Benefits of Climate Change Policies: Sea-Level Rise. Paris:* Organisation for Economic Co-operation and Development.

Nick, F.M. et al. 2013. Future sea-level rise from Greenland's main outlet glaciers in a warming climate. *Nature*. 497. 235–238.

Nordhaus. W.D. 2007. A review of the Stern review on the economics of climate change. *Journal of Economic Literature.* 45. 682–702.

———. 2008. *A Question of Balance: Weighing the Options on Global Warming Policies.* Yale University Press.

Ojea, E. 2013. Ecosystem-Based Adaptation. In A. Markandya, I. Galarraga, and E. Sainz de Murieta, eds. *Routledge Handbook of the Economics of Climate Change Adaptation*. London: Earthscan.

Olhoff, A. and C. Schaer. 2010. *Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance—A Stocktaking Report. New York:* United Nations Development Programme.

Organisation for Economic Co-operation and Development. 2009. *Policy Guidance on Integrating Climate Change Adaptation into Development Co-operation*. Report of the Joint Meeting of the OECD Development Assistance Committee and the Environment Policy Committee.

Oxfam International. 2007. *Adapting to Climate Change: What's Needed in Poor Countries and Who Should Pay*. Oxfam Briefing Paper 104.

Parry et al. 2009. *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*. London: International Institute for Environment and Development and Grantham Institute for Climate Change.

Plattner, G.K. et al. 2008. Long-term commitments projected with climate-carbon cycle models. *Journal of Climate.* 21(12). 2721–2751.

Purvis, M.J., P. D. Bates, and C.M. Hayes. 2008. A probabilistic methodology to estimate future coastal flood risk due to sea level rise. *Coastal Engineering.* 55. 1062–1073.

Ramsey. F. P. 1928. A mathematical theory of saving. *Economic Journal*. 38. 543–559.

Ranger, N. et al. 2010. *Adaptation in the U.K.: A Decision-Making Process*. Policy Brief September 2010. Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy.

Refsgaard, J.C. et al. 2013. The role of uncertainty in climate change adaptation strategies—A Danish water management example. *Mitigation and Adaptation Strategies for Global Change.* 18(3). 337–359.

Rignot, E. et al. 2011. Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise. *Geophysical Research Letters.* 38. L05503. DOI:10.1029/2011GL046583.

Robert, C.P. and G. Casella. 2004. *Monte Carlo Statistical Methods* (2nd ed.). New York: Springer.

Rogelj, J. et al. 2012. Global warming under old and new scenarios using IPCC climate sensitivity range estimates. *Nature Climate Change.* February. 2. DOI:10.1038.

Rohling, E.J. et al. 2012. Making sense of palaeoclimate sensitivity. *Nature*. 491. 683–691.

Rosenzweig, C. and F. Tubiello. 2007. *Metrics of Assessing the Economic Benefits of Climate Change Policies in Agriculture*. Paris: Organisation for Economic Co-operation and Development.

Rubinstein, R.Y. and D.P. Kroese. 2007. *Simulation and the Monte Carlo Method* (2nd ed.). New York: John Wiley & Sons.

Scheraga, J.D. and A.E. Grambsch. 1998. Risks, Opportunities, and Adaptation to Climate Change. *Climate Research*. 10. 85–95.

Schuur, E.A.G. et al. 2013. Expert assessment of vulnerability of permafrost carbon to climate change. *Climatic Change.* 119. 359–374.

Solomon, S. et al. 2009. Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences (USA).* 106(6). 1704–1709.

Springmann, M. 2012. *The Costs of Climate-Change Adaptation in Europe: A Review*. European Investment Bank. Working Paper 2012/05.

Steinschneider, S. and C. Brown. 2012. Dynamic reservoir management with real options risk hedging as a robust adaptation to nonstationary climate. *Water Resources Research.* 48(5). DOI:10.1029/2011WR011540.

Stern, N. 2007. *The Economics of Climate Change: The Stern Review*. New York: Cambridge University Press.

Tol, R. 2002. Estimates of the damage costs of climate change, Part I: Benchmark estimates. *Environmental and Resource Economics*. 22. 47–73.

———. 2009. The economic effects of climate change. *Journal of Economic Perspectives*. 23(2). 29–51.

Treasury Board of Canada Secretariat. 2007. *Canadian Cost–Benefit Analysis Guide: Regulatory Proposals (Interim).* Ottawa, Canada.

Travers, A. et al. 2012. *Ecosystem-Based Adaptation Guidance. Moving Principles to Practice*. Working document. United Nations Environment Programme.

United Nations Framework Convention on Climate Change (UNFCCC). 2009a. *Report of the Conference of the Parties on its Fifteenth Session held in Copenhagen from 7 to 19 December 2009*. Bonn.

———. 2009b. *Potential Costs and Benefits of Adaptation Options: A Review of Existing Literature*. Bonn.

———. 2011. *Assessing the Costs and Benefits of Adaptation Options: An Overview of Approaches*. The Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change. Bonn.

United States Agency for International Development (USAID). 2007. *Adapting to Climate Variability and Change: A Guidance Manual for Development Planning*. Washington, DC.

Watkiss, P. and A. Hunt. 2013. *Method Overview: Decision Support Methods for Adaptation*. Briefing Note 1. Summary of Methods and Case Study Examples from the MEDIATION Project. MEDIATION.

Weitzman, M.L. 1998. Why the far-distant future should be discounted at its lowest possible rate. *Journal of Environmental Economics and Management*. 36. 201–208.

———. 2001. Gamma discounting. *American Economic Review.* 91. 260–271.

———. 2007. A review of the Stern review on the economics of climate change. *Journal of Economic Literature*. 45. 703–724.

Westphal, M., G. Hughes, and J. Brommelhorster. 2013. *Economics of Climate Change in East Asia.* Manila: ADB.

Wilby, R.L. and S. Dessai. 2010. Robust adaptation to climate change. Weather, 65, 180-185.

Wilby, R.L. and H.J. Fowler. 2010. Regional climate downscaling. In F. Fung, A. Lopez, and M. New, eds. *Modelling the impact of climate change on water resources*. Wiley, Chichester, pp. 34–85.

Willows, R.I. and R.K. Connell, eds. 2003. *Climate Adaptation: Risk, Uncertainty and Decision-Making.* UKCIP Technical Report. Oxford, UK.

World Bank. 1992. *Economic Analysis of Projects: Towards a Results-Oriented Approach to Evaluation.* Washington, DC.

World Bank. 2010a. *Economics of Adaptation to Climate Change: Synthesis Report.* Washington, DC.

World Bank. 2010b. *Economic Evaluation of Climate Change Adaptation Projects: Approaches for the Agricultural Sector and Beyond*. Washington, DC.

Wright, E.L. and J.D. Erickson. 2003. Climate variability, economic adaptation, and investment timing. *International Journal of Global Environmental Issues.* 3(4). 357–368.

Zerbe, J.R. et al. 2011. *Towards Principles and Standards in the Use of Benefit-Cost Analysis*. Benefit-Cost Analysis Centre, University of Washington, Seattle.

APPENDIX 1
TIME HORIZONS IN ECONOMIC ANALYSIS OF ADB-FINANCED PROJECTS (1 January to 31 August 2104)

Country	Loan Approval (Month-Day)	Project Title	Time Horizon of Economic Analysis
Bangladesh	07-17	Third Urban Governance and Infrastructure Improvement(Sector) Project	The project includes four subprojects in the roads, drainage, water supply, and solid waste management sectors. Time horizon for each subproject is not explicitly mentioned in the economic analysis (EA). One reads: “Benefits and costs were estimated over each subproject’s estimated economic life” (EA, p. 1).
	06-30	Irrigation Management Improvement Project	The project provides benefits by increasing the irrigated area from 11,300 hectares (ha) to about 17,000 ha, increasing crop intensity from 107% to 187%, increasing yields by up to 50% for paddy rice, and increasing cash crop production. “The specific parameters of the methodology include …(vi) a 30-year cash flow [is] assumed in determining the [economic internal rate of return]” (EA, p. 3).
	06-27	Coastal Towns Environmental Infrastructure Project	The project includes a number of subprojects: water supply, sanitation, drainage, solid waste, roads, bridges, and cyclone shelters. “The subproject life is assumed to be 20 years with salvage values” (EA, p. 1). There is no description of the nature and computation of the salvage values.
	06-26	Flood and Riverbank Erosion Risk Management Investment Program	The overall investment program would protect 7,248 ha of land against erosion, and help protect 122,388 ha of land (including farmlands, rural homesteads, and urban areas) from flood inundation. “… key features of the methodology include the following: (i) [economic internal rates of return] and NPVs have been estimated on the basis of a 30-year net cash flow, and no residual value at the end of the cash flow period has been assumed” (EA, p. 2).
	05-19	Skills for Employment Investment Program	The investment program will help expand the capacity of the public and private sectors to provide market-responsive skills training with an enhanced job placement and/or self-employment rate from less than 40% currently to 70%. “Based on a 20-year period …” (EA, p. 5).
Bhutan	07-31	South Asia Subregional Economic Cooperation Road Connectivity Project	The outputs will be (i) the construction of roads and the establishment of trade infrastructure, (ii) the improvement of road construction and maintenance capacity, and (iii) the promotion of ecofriendly transport. “An analysis period of 20 years of operation after completion of construction was used, and the residual value for each road section at the end of analysis period was calculated for road components using straight-line depreciation” (EA, p.1).

continued on next page

Appendix 1: continued

Country	Loan Approval (Month-Day)	Project Title	Time Horizon of Economic Analysis
Cambodia	08-8	Rural Roads Improvement Project II	The project includes (i) rural road improvements, (ii) rural road asset management, and (iii) a rural road safety and community awareness program. About 729 km of rural roads will be improved to climate-resilient paved condition. "Calculations are made for 24 years starting in 2013. Road and jetty improvements are assumed to be completed in 2018, giving a benefit period of 20 years" (EA, p.1). "The residual value of the works is considered as a benefit from road improvement, representing the remaining asset value of the works, and is included at the end of the evaluation period, although the impact of the result is small when an evaluation period of more than 20 years is used. The residual value in this study is assumed to be zero" (EA, p.2).
People's Republic of China	05-14	Jiangxi Fuzhou Urban Integrated Infrastructure Improvement Project	The outputs of the project will be (i) a 12.2-kilometer (km) bus rapid transit system,(ii) an urban transport hub at the new Jiangxi Fuzhou Railway Station, (iii) river rehabilitation and "greenway" development, (iv) 10 km of station access roads, and (v) institutional strengthening and capacity building. "The period used for economic analysis was from 2013 to 2036" (EA, p. 1) "A residual value after 20 years was based on straight line depreciation of assets" (EA, p. 1).
	03-21	Yunnan Chuxiong Urban Environment Improvement Project	The project will (i) reduce flood risks and enhance public amenities, (ii) improve sanitation and public health, (iii) expand urban road networks, and (iv) promote public participation in urban development. The subprojects each have flood management, road, and solid waste management components. Time horizon is not explicitly mentioned but appears to be 25 years based on Table 2 in the EA.
	02-28	Guangdong Chaonan Water Resources Development and Protection Demonstration Project	The project will help a district increase its water supply capacity from 135,000 square meters (m3) per day to 282,000 m3 per day by (i) expanding, upgrading, and building new water supply plants; (ii) installing water delivery and distribution pipelines; (iii) providing equipment for operation and maintenance of water treatment and supply infrastructure; (iv) establishing a water quality monitoring center to underpin water quality control; and (v) installing water meters at about 38,000 households to improve the district's monitoring of water use. "The project life is 25 years, including construction; the salvage value at the end of the project life is zero. These are conservative estimates of the lifespan of the constructed water treatment plants and water distribution pipes" (EA, p. 2).
	02-27	Anhui Intermodal Sustainable Transport Project	The project will construct or upgrade 122.4 kilometers (km) of roads, including 83.4 km of rural highways and 39 km of urban roads. The project will also upgrade 48 km of the Shuiyang River to restricted class IV navigable waterway standard. "The evaluation period was 20 years for highways and 30 years for the [waterway] component to reflect its longer ramp-up period" (EA, p. 4).

continued on next page

Appendix 1: continued

Country	Loan Approval (Month-Day)	Project Title	Time Horizon of Economic Analysis
India	07-3	Assam Power Sector Investment Program	The investment program objectives are to increase capacity and efficiency of power generation and distribution systems. The investment components include the construction of two power generation projects with total new capacity of 190 megawatts, and installation of distribution assets in selected urban areas of Assam. "The economic evaluation covers 20 years, including 2 years for capital investment and construction. Investment is assumed to take place during 2014–2015, and benefits are assumed to be realized from 2016. Asset residual values are ignored (their inclusion makes negligible difference to the economic internal rate of return)" (EA, p. 3).
	03-28	Karnataka Integrated Urban Water Management Investment Program	The investment program aims to improve water resource management in urban areas. The investment program will (i) provide investment support to modernize and expand urban water supply and sanitation; (ii) strengthen institutions to improve water use efficiency, productivity, and sustainability; and (iii) pursue innovative technologies and instruments, such as public–private partnerships or reform-oriented incentive funds. "Subprojects were analyzed over 20 years, excluding the 4 years of project implementation. Assets established by the subprojects were assumed to have a useful life of 30 years. Salvage values were assumed at the end of the analysis period" (EA, p. 4).
	03-28	South Asia Subregional Economic Cooperation Road Connectivity Investment Program	The project will improve the road connectivity and efficiency of the international trade corridor by expanding about 500 kilometers of roads in North Bengal and the northeastern region of India. Time horizon is 20 years, not including 3 years of project implementation. "A straight-line depreciation method is used to calculate the salvage value of project elements at the end of the analysis period. Among the project elements, bituminous components are assumed to have a life of 20 years or less with periodic renewal as needed and will have no salvage value. The pavement structure below bituminous layer in the widening portion is assumed to have a 30-year life for salvage value calculation. Bridges and cross-drainage structures can have a life of more than 40 years. Assuming a 40-year life for all structures, the salvage value was calculated on a straight-line depreciation method" (EA, p. 3).
Kiribati	05-14	South Tarawa Sanitation Improvement Sector Project	The proposed project will support improvements to the health of communities in South Tarawa. This will be achieved through rehabilitation and upgrading of sanitation infrastructure. "The project operating period is 20 years following full commissioning of the initial sewerage investments in 2015" (EA, p. 2).
Nepal	07-4	South Asia Subregional Economic Cooperation Power System Expansion Project	The project comprises electricity transmission system expansion, grid substation reinforcement, distribution system augmentation, and mini-grid-based renewable energy development subprojects. Time horizon is not explicitly mentioned but appears to be 25 years based on Table 3 of the EA.
Pakistan	06-27	National Highway Network Development in Balochistan Project	The proposed project will rehabilitate two-lane national highways. Local community facilitation centers will also be developed along the project roads to enable local communities to take advantage of the improved mobility through rehabilitated project roads. "Traffic forecasts were made for the 20-year period from 2018 to 2037" (EA, p. 3).

continued on next page

Appendix 1: continued

Country	Loan Approval (Month-Day)	Project Title	Time Horizon of Economic Analysis
Solomon Islands	05-12	Provincial Renewable Energy Project	The project includes a 750-kilowatt run-of-river hydropower plant and 9.7 kilometers of transmission line. "The economic analysis was carried out considering a 30-year lifetime of the asset after commissioning in 2018" (EA, p. 6). "No residual value at the end of the 30-year period" (EA, p. 1).
Sri Lanka	07-15	Green Power Development and Energy Efficiency Improvement Investment Program	The investment program includes (i) construction of a 30-megawatt run-of-river hydropower plant, (ii) transmission infrastructure enhancement for absorption of intermittent renewable energy, (iii) network efficiency improvements, (iv) demand-side management interventions, and (v) project management and institutional capacity development. "A 25-year period was used for the evaluation with no terminal value considered for the investment" (EA, p. 2).
	03-28	Skills Sector Enhancement Program	The project will increase skills of the labor force. "A conservative time period of 20 years (until 2034) is assumed for both the benefits and costs streams" (EA, p.6).
Uzbekistan	07-15	Takhiatash Power Plant Efficiency Improvement Project	The project involves constructing two combined cycle gas turbine units, each with an installed capacity of 255 megawatts, and retiring three turbines that are between 39 and 44 years old. "... an operating period of 25 years after construction" (EA, p. 1).
Viet Nam	02-20	Sustainable Urban Transport for Ho Chi Minh City Mass Rapid Transit Line 2 Project	The project will support the effective and sustainable use of the new Line 2 of the Ho Chi Minh City mass rapid transit (MRT) network now being developed with ADB assistance. It will enhance the connectivity between the MRT Line 2 stations and other modes of public and private transport, and strengthen urban transport policies and regulations. The economic assessment covered 35 years, 2014–2048, comprising 5 years of project preparation and construction during 2014–2018 and a 30-year benefit period.

APPENDIX 2
ON THE DISCOUNT RATE

Under some circumstances, including the absence of or ignoring the presence of uncertainty, the approach based on the rate of social time preference leads to the Ramsey rule for discounting (Ramsey 1928).

The Ramsey rule specifies the value of the discount rate as where:

- r   is the economic (social) discount rate.
- δ is the rate at which society discounts the utility of present versus future consumption. A value of zero for this parameter implies that for any given level of consumption, the existing generation considers the utility of future generations to be equal to its own.
- γ is the marginal utility of consumption with respect to consumption (change in the utility of consumption as consumption increases). This parameter describes how fast the marginal utility of consumption decreases as consumption increases. The higher is the value of γ, the more rapidly is the marginal utility of consumption assumed to decrease.
- g is the percentage change in per capita consumption.

Imputing specific values to δ and γ could be based on ethical principles or be inferred from decisions in financial markets (see Arrow et al. 2012 for a discussion on the use of the Ramsey formula in the context of climate change).

As shown Table A2.1, assumptions pertaining to the value of the above parameters yield a value for the economic discount rate.

Table A2.1: Setting the Discount Rate Using the Ramsey Rule

	δ	γ	g	r
Weitzman (2007)	2.0%	2	2.0%	6.0%
Nordhaus (2007)	1.0%	2	2.0%	5.0%
Stern (2007)	0.1%	1	1.3%	1.4%
U.K. (H.M. Treasury 2003)	1.5%	1	2.0%	3.5%
France (Lebegue 2005)	0%	2	2.0%	4.0%

Source: Adapted from Gollier, C. 2012. *Pricing the Planet's Future: The Economics of Discounting in an Uncertain World*. Princeton and London: Princeton University Press.

More specifically, both France and the UK have adopted a declining schedule of social discount rate. The rates reported in Table A2.1 apply for the first 30 years of the project horizon, with lower values of the discount rate are recommended for subsequent years.

In the absence of uncertainty, application of the Ramsey rule implies the use of a single, *constant* discount rate applied through the time horizon of the economic analysis.

The presence of uncertainty may call for the use of a declining (as opposed to constant) discount rate. In the presence of uncertainty about the rate of growth of consumption, the Ramsey rule can be modified by including a third term reflecting uncertainty. If shocks to the per capita growth rate of consumption are correlated over time, then application of the Ramsey rule may lead to a decreasing structure for the discount rate.

More recently, Weitzman (1998, 2001) has shown that uncertainty about which value of the discount rate to use must result in a declining schedule of certainty-equivalent discount rates.

These arguments explain, for example, that France, Norway, and the United Kingdom among others, have adopted a declining schedule of discount rate.[46]

Detailed mathematical demonstrations of the rationale underpinning the use of declining discount rates are available in Cropper (2012), Gollier (2012), and Weitzman (1998, 2001). Below is a much simplified presentation.

Consider the present value of $1,000 received at various points in time T in the future (T = 5, 10, 20, 30, 40, 50, and 100 years) calculated with a discount rate of 1%, 4%, and 7%. As shown in Table A2.2, for any given T, the higher the discount rate, the lower the present value; and, for any given discount rate, the higher T, the lower the present value.

Table A2.2: Present Value of $1,000 Received in T Years from Now Using Different Discount Rates

	T = 5	T = 10	T = 20	T = 30	T = 40	T = 50	T = 100
1%	951.46	905.28	819.54	741.92	671.65	608.03	369.71
4%	821.93	675.56	456.39	308.32	208.29	140.71	19.80
7%	712.99	508.35	248.42	131.37	66.78	33.95	1.15

46 In the UK, for example, following H.M. Treasury (2003), a discount rate of 3.5% should be used for costs and benefits occurring in less than 30 years. For periods longer than 30 years, a declining forward discount rate is recommended. For costs and benefits between 31 and 75 years, 3% is used. This declines to 2.5% for costs and benefits between 76 and 125 years, 2% between 126 and 200 years, 1.5% between 201 and 300 years, and 1% for costs and benefits beyond 301 years.

Now assume uncertainty about which value of the discount rate to use. Assume that the discount rate may be 1% or 7% with equal probability. Note that the expected discount rate is 4%. Then, the expected present value is shown in Table A2.3. For any given T, note that the present value (PV) at the certain 4% (in Table A2.2) is smaller than the PV at the *expected* 4% (in Table A2.3). Note also that the difference between PV(4%) and PV(expected 4%) increases as T increases.

Table A2.3: Present Value of $1,000 Received in T Years from Now with Expected Discount Rate of 4%

	T = 5	T = 10	T = 20	T = 30	T = 40	T = 50	T = 100
Expected 4%	832.23	706.82	538.98	436.65	369.22	320.99	185.43

The reason for this result lies in the fact that the present value function is strictly convex in the discount rate, as shown in Figure A2.1 (more generally, this result is known as Jensen inequality). Note in the figure that the degree of convexity (the curvature of the function) increases as T increases (the higher T, the more pronounced the bend in the PV function).

From Figure A2.1, now solely consider the case of T = 100 as shown in Figure A2.2. PV(4%) is $19.80 while PV(expected 4%) is $185.43. One may then ask the following question: What would be the discount rate (the certain discount rate) that would yield the same present value as the uncertain (or expected) discount rate? This value is shown as R in the figure below and is referred as the "certainty-equivalent discount rate" (in the context of the numbers used in this example, the certainty-equivalent discount rate is approximately 1.69%).

Figure A2.1: Convexity of the Present Value Function

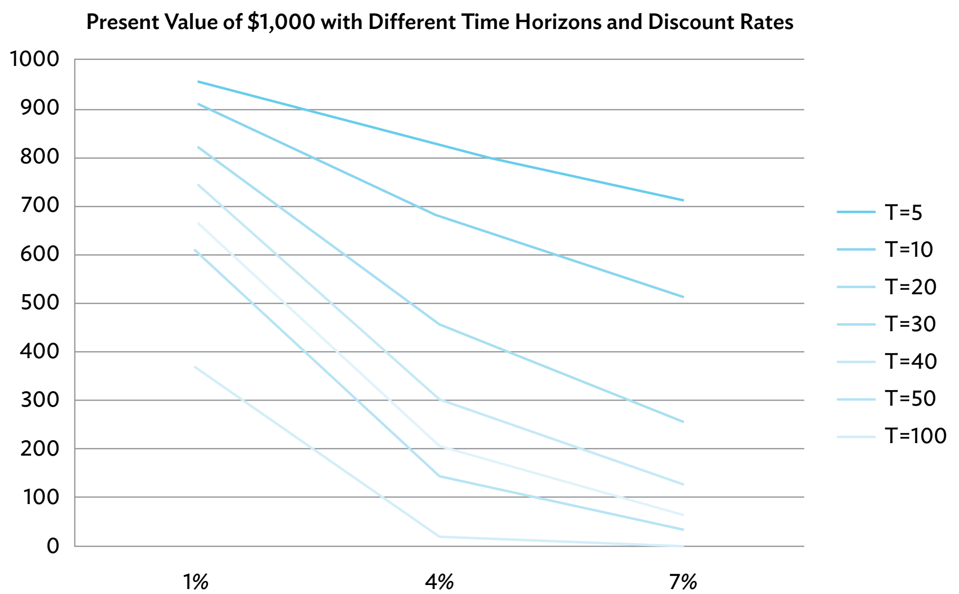
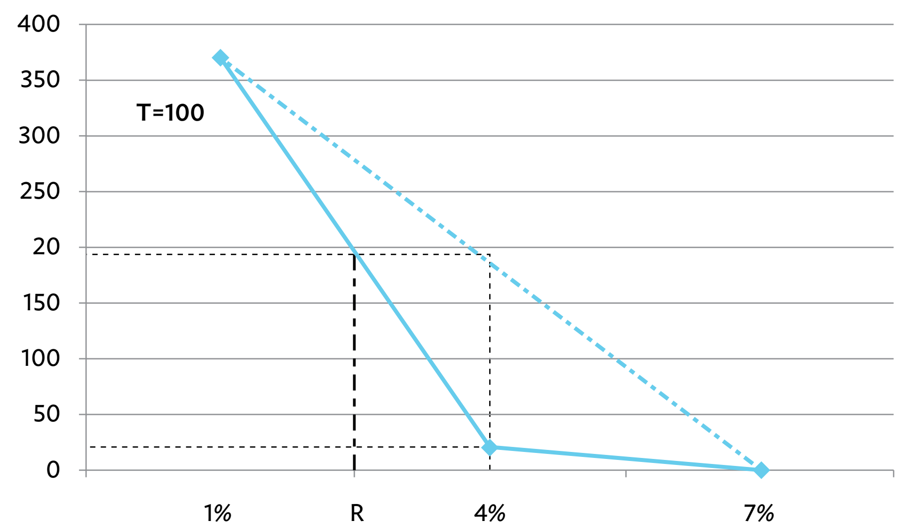


Figure A2.2: Certainty Equivalent Discount Rate



Note that the difference between the actual discount rate (of 4% in this example) and the certainty-equivalent discount rate increases as the degree of convexity of the PV function increases: the greater the degree of convexity, the lower the certainty-equivalent discount rate. And since this degree of convexity increases as T increases, we thus conclude that uncertainty about the value of the discount rate to use must yield to the use of certainty equivalent discount rate which is declining at time horizon increases.

APPENDIX 3
SENSITIVITY ANALYSIS IN ECONOMIC ANALYSIS OF ADB-FINANCED PROJECTS (1 January to 31 August 2014)

Country	Loan Approval (Month-Day)	Project Title	Sensitivity Analysis
Bangladesh	07-17	Third Urban Governance and Infrastructure Improvement (Sector) Project	• 10% increase in costs (A) • 10% decrease in benefits (B) • (A) and (B) combined • Switching values estimated and presented
	06-30	Irrigation Management Improvement Project	• Reduction in benefits: Reduction in irrigated area from 17,000 ha (baseline) to 15,000 or 13,000 • Reduction in benefits: Start-up of improved irrigation system increases from Year 2 (baseline) to Year 3 or Year 4 • Switching values estimated and presented
	06-27	Coastal Towns Environmental Infrastructure Project	• 20% increase in capital cost (A) • 20% increase in operation and maintenance(O&M) cost • 20% decrease in benefits (B) • (A) and (B) combined • 1-year delay
	06-26	Flood and Riverbank Erosion Risk Management Investment Program	• 15% increase in cost • 15% decrease in benefits • Switching values estimated and presented
	05-19	Skills for Employment Investment Program	• 10% increase in cost (A) • 10% decrease in benefits (B) • (A) and (B) combined • Optimistic and pessimistic cases are estimated and presented
Bhutan	07-31	South Asia Subregional Economic Cooperation Road Connectivity Project	• 10% increase in cost (A) • 10% decrease in benefits (B) • 1-year delay (C) • (A), (B), and (C) combined • Switching values are presented and calculated
Cambodia	08-8	Rural Roads Improvement Project II	• Costs increase by 20% (A) • Vehicle operating costs decrease by 20% (B) • Base traffic decreases by 20% • Traffic growth rate decreases by 20% • No time benefits • No traffic generated • (A) and (B) combined

continued on next page

Appendix 3: continued

Country	Loan Approval (Month-Day)	Project Title	Sensitivity Analysis
People's Republic of China	05-14	Jiangxi Fuzhou Urban Integrated Infrastructure Improvement Project	• 20% increase in cost • 20% decrease in value of time • 20% decrease in vehicle operating costs • 20% less population than predicted
	03-21	Yunnan Chuxiong Urban Environment Improvement Project	• 10% increase in capital cost (A) • 10% decrease in benefits (B) • 1-year delay (C) • (A), (B), and (C) combined • Switching values are presented and calculated
	02-28	Guangdong Chaonan Water Resources Development and Protection Demonstration Project	• 10% increase in capital cost • 10% decrease in benefits • 10% increase in O&M cost • 1-year delay • Switching values are presented and calculated
	02-27	Anhui Intermodal Sustainable Transport Project	• 20% increase in capital cost • 20% decrease in benefits • 2-year delay
India	07-3	Assam Power Sector Investment Program	• Capital cost increases by 15% (A) • O&M cost increases by 20% (B) • Benefits decrease by 20% (C) • 1 year delay (D) • (A), (B), (C), (D) combined • Switching values are estimated and presented
	03-28	Karnataka Integrated Urban Water Management Investment Program	• 10% increase in capital cost (A) • 10% increase in O&M (B) • 10% decrease in benefits (C) • 1-year delay (D) • Worst-case scenario is estimated but its meaning is not explained • Switching values are presented and calculated
	03-28	South Asia Subregional Economic Cooperation Road Connectivity Investment Program	• 15% increase in capital cost (A) • 15% decrease in benefits (B) • (A) and (B) combined • Switching values are presented and calculated
Kiribati	05-14	South Tarawa Sanitation Improvement Sector Project	• 20% increase in capital cost (A) • 20% increase in O&M • 20% decrease in benefits (B) • (A) and (B) combined • Switching values are presented and calculated
Nepal	07-4	South Asia Subregional Economic Cooperation Power System Expansion Project	• 10% increase in capital cost (A) • 20% increase in O&M (B) • 10% decrease in benefits (C) • 20% increase in cost of supply (D) • (A), (B), (C), and (D) combined • Switching values are presented and calculated
Pakistan	06-27	National Highway Network Development in Balochistan Project	• 20% increase in capital cost • 20% decrease in vehicle operating costs • 1% reduction in gross domestic product growth rate • 1-year delay • Switching values are presented and calculated

continued on next page

Appendix 3: continued

Country	Loan Approval (Month-Day)	Project Title	Sensitivity Analysis
Solomon Islands	05-12	Provincial Renewable Energy Project	• 10% increase in cost (A) • 10% decrease in revenues (B) • (A) and (B) combined
Sri Lanka	07-15	Green Power Development and Energy Efficiency Improvement Investment Program	• 10% increase in capital cost (A) • 10% decrease in willingness to pay revenues (B) • 10% increase in O&M cost (C) • (A), (B), and (C) combined
	03-28	Skills Sector Enhancement Program	• Lower wage premium increase of 1.5% • Lower employment rate of 65% • Lower graduation rate of 75% • Higher graduation rate of 85% • Higher employment rate of 75%
Uzbekistan	07-15	Takhiatash Power Plant Efficiency Improvement Project	• 20% increase in capital cost • 20% increase in O&M cost • 20% decrease in revenues
Viet Nam	02-20	Sustainable Urban Transport for Ho Chi Minh City Mass Rapid Transit Line 2 Project	• 10% increase in capital cost • 10% decrease in benefits • 5% increase in capital cost and 5% decrease in benefits

Economic Analysis of Climate-Proofing Investment Projects

Climate change represents an increasing threat to the continued development of the people, preservation of ecosystems, and economic growth of Asia and the Pacific. Mainstreaming climate risk management in all aspects of development is thus key to an effective transition to climate-resilient development pathways. ADB's climate risk management framework aims to reduce risks resulting from climate change to investment projects in Asia and the Pacific. A key step in this framework is the technical and economic valuation of climate-proofing measures. This report describes the conduct of the cost-benefit analysis of climate proofing investment projects. An important message is that the presence of uncertainty about climate change does not invalidate the conduct of the economic analysis of investment projects, nor does it require a new type of economic analysis. However, the presence of uncertainty does require a different type of decision-making process in which technical and economic expertise combine to present decision makers with the best possible information on the economic efficiency of alternative designs of investment projects.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to the majority of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org