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Decision-making Frameworks

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EXECUTIVE SUMMARY

Scope for and New Developments in Analyses for Climate Change Decisions

Climate change is profoundly different from most other environmental problems with which humanity has grappled. A combination of several features gives the climate problem its unique feature, which include:
- public good issues that arise from the concentration of greenhouse gases (GHGs) in the atmosphere (and require collective global action);
- the multiplicity of decision makers (ranging from global decision-making frameworks (DMFs) down to the micro-level of firms and individuals);
- the heterogeneity of emissions; and
- the consequences of emissions around the world.

Moreover, the long-term nature of climate change originates because it is the concentration of GHGs that is important, rather than annual emissions; this feature raises the thorny issues of intergenerational transfers of wealth and environmental good and bad outcomes. Next, human activities associated with climate change are so widespread that narrowly defined technological solutions are impossible and the interactions of climate policy with other broad socioeconomic policies are strong. Finally, large uncertainties or in some areas even ignorance characterize many aspects of the problem and require a risk management approach to be adopted in all DMFs that deal with climate change.

Experiments with cost–benefit models framed as a Bayesian decision-analysis problem show that optimal near-term (next two decades) emission paths diverge only modestly with perfect foresight and even with hedging for low-probability, high-consequence scenarios. Cost-effectiveness analyses seek the lowest cost that will achieve an environmental target by equalizing the marginal costs of mitigation across space and time. Long-term cost-effectiveness studies estimate the costs to stabilize atmospheric carbon dioxide (CO_2) concentrations at different levels. While there is a moderate increase in the costs when passing from a 750 ppmv to a 550 ppmv concentration stabilization level, there is a larger increase in costs passing from 550 ppmv to 450 ppmv unless the emissions in the baseline scenario are very low. The total costs of stabilizing atmospheric carbon concentrations are very dependent on the baseline scenario: for example, for scenarios focusing on the local and regional aspects of sustainable development costs are lower than for other scenarios. Rather than seeking a single optimal path, the tolerable windows or safe landing approaches seek to delineate the complete array of possible emission paths that satisfy externally defined climate impact and emission cost constraints. Results indicate that a delay in near-term effective emission reductions can drastically reduce the future range of options for relatively tight climate change targets. Less tight targets offer more near-term flexibility.

International Regimes and Policy Options

Different mitigation policy options include the timing of responses to climate change, the choice between mitigation and adaptation responses, the role of technological innovation and diffusion, the choice between domestic action and the adoption of international mechanisms, the combination of climate change mitigation with actions towards other environmental or socio-economic objectives, and others. The costs and benefits of these crucially depend on the characteristics of the international agreement on climate change that is adopted. In particular, they depend upon two main features of the international regime: the number of signatories, and the size of their quantitative commitment to control GHG emissions. The number of signatories depends on how equitably the commitments of the participants are shared. Cost-effectiveness (minimizing costs by maximizing participation) and equity (the allocation of emissions limitation commitments) are therefore strongly linked.

There is therefore a three-way relationship between the design of the international regime, the cost-efficiency of climate policies, and the equity of the consequent economic outcomes. Thus, it is crucial to design the international regime in a way that increases both its efficiency and its equity. The literature presents different strategies to optimize an international regime. For example, countries can be encouraged to participate in an international group committed to specific emissions limits and targets if the equity (and therefore efficiency) is increased by a larger agreement. This may include measures like an appropriate distribution of targets over time, the linkage of the climate debate with other issues (“issue linkage“), the use of financial transfers to affected countries (“side payments”), and technology transfer agreements.

Linkages to National and Local Sustainable Development Choices

Government structures involved in the decision-making process vary considerably among countries. Institutional articulation remains one of the critical factors affecting the consolidation of an effective decision-making process related to sustainable development. Even if rules and regulations exist to assign competence, tasks, and responsibilities among the institutions involved, a considerable gap exists between what might be desirable and what, for the most part, is practised. In this context, policies related to sustainable development are no longer seen as a hierarchical, government-controlled chain of commands, but rather as an open process in which the principles of "good governance"–transparency, participation, pluralism, and accountability–become the key elements of the decision-making process.

A critical requirement of sustainable development is the capacity to design policy measures that exploit potential synergies between national economic growth objectives and environmentally focused policies without hindering development and in accordance with national strategies. As also discussed in Chapters 1 and 2, climate change mitigation strategies offer a clear example of co-ordinated and harmonized policies that take advantage of the synergies between the implementation of mitigation options and broader objectives. The potential linkages between climate change mitigation issues and economic and social aspects have also brought an important shift in the focus of mitigation analysis literature. The three perspectives introduced in Chapter 1 (cost-effectiveness, equity and sustainability) illustrate this shift and broaden the array of options, for example by including options for institutional and behavioural changes. From being confined to project-by-project or sector-based approaches, analyses and studies are increasingly concerned with the use of broader policy issues as mechanisms to reduce GHG emissions. Thus the alternative energy paths of low carbon futures in developing countries can be compatible with national objectives. Although environmental concerns, and climate change issues in particular, were not explicitly addressed by macroeconomic and sectoral policies, analyzed country cases show clear synergies between reform policies and environmental improvements. It is also important to underline that for the elements that make up policies at different levels to operate in a mutually reinforcing manner, the creation of appropriate communication and information channels should be given special attention.

The private sector has played an important role in the development and transfer of energy efficiency technologies, which reduce the emission of GHGs, and it is becoming increasingly active in developing and transferring renewable energy technologies. Large enterprises can establish research and development (R&D) institutions on their own or jointly with other research centres to provide support to technological innovation and the integration of production and research. On the supply side, the government can play an important role in R&D and creating an enabling environment for technology transfer. While introducing technologies to mitigate and adapt to climate change, the developing countries should consider that the introduction of such technology could generate economic benefits and promote sustainable development. In many cases of technology transfer, much attention was paid to the introduction of technologies and a high cost was paid to procure expensive technological facilities, but less effort was applied to the digestion, absorption, and innovation of the introduced technologies. Information can play a guiding role in technology transfer. To enable sound decision-making, the up-to-date information on the current status of technology research and development, the technical and economic evaluation of technologies, and the sources of technologies should be available.

Key Policy-relevant Scientific Questions

Answers to policy-relevant scientific questions need to draw on the vast material presented in this volume. These questions are concerned with the best possible current action with a view to a huge array of possible futures. Decisions need to be made regarding the short-term balance of various types of actions (mitigation, adaptation, information acquisition), their timing (in absolute terms and relative to each other), their location (of mainly mitigation activities), the character and content of international agreements, and the mode and broader policy context of implementation.

Striking the appropriate balance between mitigation and adaptation will be a tedious process. The need for, extent, and costs of adaptation measures in any region will be determined by the magnitude and nature of the regional climate change driven by shifts in global climate. How global climate change unfolds will be determined by the total amount of GHG emissions that, in turn, reflects nations' willingness to undertake mitigation measures. Balancing mitigation and adaptation efforts largely depends on how mitigation costs are related to net damages (primary or gross damage minus damage averted through adaptation plus costs of adaptation). Both mitigation costs and net damages, in turn, depend on some crucial baseline assumptions: economic development and baseline emissions largely determine emission reduction costs, while development and institutions influence vulnerability and adaptive capacity.

Options to mitigate climate change include actual emission reductions and CO_2 sequestration, investments in developing technologies that will make future reductions cheap relative to their current costs, institutional and regulatory changes to modify current decisions that distort in favour of GHG-emitting action, and others. Their relative weight in an optimal near-term portfolio of mitigation actions crucially depends on the assumptions behind the various mitigation-cost estimates and about the preconditions and future availability of inexpensive technologies. Estimates of costs of drastic near-term reductions tend to be high, but the proper way to encourage technological development remains heavily debated.

In principle, costs of near-term emission reductions could be reduced by using international flexibility mechanisms to realize reductions where they are least expensive. While there is a broad agreement on the cost-reducing effect of international flexibility mechanisms, there are concerns about their implications for incentives to technological development as well as about the political (domestic and international) and practical pitfalls of their implementation. In addition to costs, climate change impacts and mitigation efforts raise a whole array of equity issues.

Much of the debate about climate change mitigation revolves around the broader issue of development and the unequal distribution of wealth among countries of the world. Views diverge widely. Is climate change an opportunity to solve the problems of sustainable development and global distribution of wealth? Or would broadening the scope of the already complex and controversial issue of climate change run the risk of neither solving the climate problem nor improving prospects for sustainable development? This reports takes the view that by taking into account the broader perspective of sustainable development the portfolio of mitigation policies is enhanced. A central issue in linking development and climate concerns is technological transfer that could help less-developed countries speed-up their development and control GHG emissions at relatively low costs. Opportunities are ample, but barriers are significant also.

10.1 Introduction

10.1.1 Chapter Overview

The preceding chapters in this volume assess the scientific literature on specific aspects of climate change economics and policy. This chapter is intended to synthesize the most important policy-relevant scientific results by taking several cuts across the material. This chapter begins with a presentation of the special features of climate change in the context of how they affect decision-making in different frameworks. This is followed by a list of analytical frameworks adopted by scientists to provide advice to decision makers and by an overview of the most important new developments since the Second Assessment Report (SAR). This section closes with notes on decision-making processes and implications of uncertainty for the robustness of choices.

Section 10.2 presents an assessment of key insights from the economics and political science literature into international regimes and policy options. The chief issue addressed in the section is how international institutions for addressing climate change, such as the United Nations Framework Convention on Climate Change (UNFCCC), are simultaneously shaped by and influence national policy choice.

Section 10.3 considers the problem of local and national climate policy formulation in the broader context of sustainable development objectives. The interactions of development and environmental policy objectives, particularly as they affect non-Annex I nations, are discussed.

Section 10.4 looks at a series of policy-relevant scientific questions related to global and international climate policy in more detail. It focuses on what has been learned from work that examined decision making at the global scale. While much of this literature is also cognizant of the regional decisions that accumulate to determine global aggregates, it is united by a global focus, common to all of the work discussed in the section. It explores what is known about costs and benefits of actions, the timing and composition of policy responses, and the influence of equity and fairness considerations on policy. Finally, some concluding remarks and an outline of future tasks are presented in the closing section.

The long tradition of using the terms decision analysis (and frameworks) and decision making (and frameworks) largely interchangeably, and both meaning scientific inquiries to serve decision makers, has resulted in some confusion in the case of climate change. With a view to the political sensitivity of the issue, it is important to clarify the terminology here at the beginning of this chapter. Toth (2000) proposes a simple scheme to make a clear distinction to recognize the fine borderline between a policy-relevant scientific assessment and policy making proper. Climate change decision-making and decision analysis intended to support it can be structured in three major domains: decision making *per se* (the act of formulating decisions), decision analysis (aimed at providing information for decision makers), and process analysis (investigating procedures of decision making). The last two are sometimes difficult to separate and they overlap in certain areas, but the distinction is still useful.

DMFs relevant to the climate problem have several levels. They stretch from global and supranational fora through national and regional institutions down to the micro-level of companies, families, and individuals. At each level, it is useful to distinguish two parts of these DMFs: institutions that provide the boundary conditions (jurisdictions, procedural rules, the body of earlier agreements, etc.) and processes that fall within these frameworks (negotiations, lobbying, persuasion). At the global level, for example, UNFCCC provides the institutional part and negotiations represent the process part of the DMF.

To keep the term comprehensive and flexible, decision-analysis frameworks (DAFs) are defined as analytical techniques aimed at synthesizing available information from many (broader or narrower) segments of the climate problem to help policymakers assess the consequences of various decision options within their own jurisdictions. DAFs organize climate-relevant information in a suitable framework, apply a decision criterion (based on some paradigms or theories), and identify options that are better than others under the assumptions that characterize the analytical framework and the application at hand. A broad range of DAFs has been used to provide substantial information for the various DMFs involved in climate decisions at various levels. The most important ones are depicted later in this section.

The third domain is process-analysis frameworks (PAFs), which involve assessments of the decision-making process and provide guidance for decision making in two main areas. The first is concerned with institutional framework design, that is how to build policy regimes that address the problem effectively (Victor *et al*., 1998; Young, 1999). The second looks at procedures of decision making at various levels. The bulk of the literature on climate change addresses global regime-building in framework analysis and international negotiations in procedure analysis (Kremenyuk, 1991). Pertinent lessons from this literature are assessed in Section 10.2.

The objective in this chapter is to provide a critical appraisal of policy-oriented analyses and to summarize the emerging insights in a form that allows policymakers to make informed judgements within the various DMFs. It is clearly not intended to inflict any particular position upon the policymakers.

10.1.2 Scope of the Problem

Climate change is a problem that is inherently different from other environmental problems with which humanity has grappled, because the assumption that prior experience with other air-pollution problems is a good model upon which to base climate policy responses fails at many levels. At least six unique features characterize the issue.

10.1.2.1 The Problem Is Global

Public goods issues

Traditional environmental air-pollution problems have been amenable to local solutions. The dirty air in a North American city is of no direct consequence to a city in New Zealand. With climate change it is the emissions of all sources in all nations that determine the concentration of greenhouse gases (GHGs) in the atmosphere. As a consequence, the climate change problem is inherently a public goods problem. That is, the climate that everyone enjoys is the product of everyone's behaviour. No single individual or nation can determine the composition of the world's atmosphere. Any individuals' or nations' actions to address the climate change issue, even the largest emitting nation acting alone, can have only a small effect. As a consequence, individuals and nations acting independently will provide, together, fewer resources than all individuals and nations would if they acted in concert. This characteristic provides an important motivation for collective, global action.

Multiplicity of decision makers

Multiplicity of decision makers also implies that there are limits to collective actions. Decisions by actors at a wide range of levels–global governmental organizations, nation states, regional governments, private individuals, multinational firms, local enterprises–all matter. The global nature of the problem also implies that the full breadth of human social structures is encompassed. This in turn implies that a diversity of policy responses is needed. Policy responses that are effective and appropriate in one social context may be completely inappropriate in another.

Heterogeneity

Emissions and consequences are also heterogeneous around the world. This exacerbates the basic public goods nature of the problem. Countries are distributed across a spectrum of high emitters to low emitters and high impacts to low impacts. Nations with high emissions and low expected impacts have a high potential to control concentrations, but little incentive. On the other hand, nations with low emissions and high impacts have great incentive to control emissions, but little capability. While side payments could, in principle, resolve this dilemma, transaction costs may be significant and the present income distributions may lead to unacceptable outcomes. Furthermore, most of the people who will be directly affected by the problem have not been born yet, which limits their ability to negotiate. Both emissions and the capability to mitigate carbon emissions to the atmosphere are unevenly distributed around the world. A dozen countries control 95% of conventional carbon-based energy resources–conventional oil, conventional gas, and coal. Unconventional resources–deep gas, methane hydrates, and shales–while presently expensive relative to conventional fuels, have an unknown distribution in potentially vast quantities. Fifteen nations emit more than 75% of the world's annual carbon emissions.

10.1.2.2 The Problem Is Long Term

It is concentrations not emissions that matter

Climate change is related to the concentration of GHGs and not to any individual year's emissions. Carbon dioxide (CO_2) concentrations are closely related to the net accumulation of emissions over long periods of time. That is, it is the sum of emissions over time that determines the atmospheric concentration. Any individual year's emissions are only marginally important[1]. Average residence times for GHGs can range up to thousands of years for some of the anthropogenic species. Strategies to control net emissions must account for long periods of time in a meaningful way. The ultimate objective of the UNFCCC is the "stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC 1993, Article 2).

Intergenerational transfers are inevitable

The consequences of climate change will be visited primarily on those who are alive in the future. The present generation has inherited its atmosphere and associated climate from its ancestors. While individuals and governments make many decisions that affect future generations, most of these decisions are undertaken inadvertently. It is impossible to avoid the intergenerational wealth-transfer issue when addressing the climate problem. That most of the affected parties are not present to participate in the decision-making process raises complicated ethical questions. The implications of their absence are not immediately obviously. Future generations have a stake both in the environmental resources, such as climate, that they inherit, and in other wealth that is passed down to them. Sacrifices that are made by the present generation for the good of its descendants will alter the composition of wealth (e.g., environmental versus material) that is transferred from the present to the future, as well as the magnitude of the transfer. As climate change is anticipated to be greater in the future than it is at present, those who live in the future will reap most of the benefits that accrue to near-term actions to limit emissions. Intergenerational asymmetry can lead to a form of public goods problem in which the willingness to undertake emissions mitigation in the near-term may be less than would have been the case if the decision makers lived infinitely. Also implied is a greater sensitivity to emission-limitation costs than would be the case if the present generation lived to benefit from its emissions-mitigation actions.

To limit the concentration of atmospheric carbon dioxide, global carbon emissions must eventually peak and then decline

This result follows from the nature of the carbon cycle, as it is

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[1] Clearly, the time path of emissions over a longer time period does affect the rate of change of concentrations and associated climate changes.

presently understood. While non-CO_2 GHGs with relatively short life times, such as methane (CH_4), have an atmospheric concentration that is stable with a stable rate of annual emission, CO_2 does not. The cumulative net introduction of carbon emissions from terrestrial reservoirs, such as fossil fuels or biological carbon, through (for example) energy production and use or land-use change, determines the long-term, steady state, atmospheric CO_2 concentration. Carbon cycle models require net emissions to asymptotically approach zero, though the process can take centuries. Most, but not all, emissions scenarios anticipate that, in the absence of a concern for climate change, future GHG emissions will continue to rise rather than fall (IPCC, 2000b). Where reference emissions scenarios exhibit increasing emissions over time, most of the emissions mitigation required to stabilize the concentration of carbon must occur in the future, with the deviation from the profile required for stabilization growing with time.

While emissions limitation is a policy response, it is not the only policy response available to decision makers
In addition to emissions limitations, policymakers have a wide array of other tools at their disposal including knowledge gathering, research and development of technologies to reduce emissions and enhancing the resilience of societies experiencing climate change. The optimal and actual mix of policy responses will vary over time.

10.1.2.3 Associated Human Activities Are Pervasive

Control of greenhouse gas concentrations implies eventual limitations on energy-related emissions
Energy is the single largest source of GHG emissions. It is responsible for approximately 80% of net carbon emissions to the atmosphere. While net emissions of carbon are associated with fossil fuel combustion, the carbon-to-energy ratio varies between high-carbon fuels, such as coal, and low-carbon fuels, such as CH_4, approximately by a factor of two. Technologies such as hydroelectric power, nuclear fission, wind power, and solar power are generally treated as if they have little or no direct carbon emissions, though this may not be the case. For example, CH_4 may be released in the process of creating a hydroelectric facility and carbon may be released in the manufacture of cement used in nuclear power reactors. Technologies do exist that can biologically sequester or physically remove and store carbon. Thus, in principle, controlling energy-related carbon emissions is possible for several sources of carbon emissions without foregoing fossil fuel use. These technologies are discussed in Chapter 3.

Narrowly defined technological solutions are unavailable, but a broad development and deployment of technology is key to controlling the cost of emissions limitation
Emissions of GHGs are associated with an extraordinary array of human activities. CO_2 emissions are associated with the combustion of fossil fuels and changes in land-use. They are thus affected by activities that range from, for example, household heating and cooling to commercial lighting and appliances, to the transportation of goods and provision of services, to the manufacture of materials, to the growth and harvest of crops, and to the generation of electric power. As a consequence, GHG emissions are greatly affected by other exogenous and non-climate-policy factors. Narrowly defined technological solutions, such as were available to address the problem of stratospheric ozone depletion, are impossible for the climate issue. While no single technology provides a complete solution to the problem of controlling emissions of GHGs, a significant set of existing, emerging, and potential technologies is available to mitigation climate change, as discussed in Chapters 2, 3 and 4[2].

Policy interactions will be significant
Future emissions depend to a large degree on the rate and direction of technological developments in a broad array of human endeavours. For example, China's policies to stabilize its population size, taken for reasons unrelated to climate change, will have a profound effect on Chinese emissions of GHGs to the atmosphere. Policies to control non-GHG air pollutants can greatly affect GHG emissions. For example, measures to substitute natural gas and non-carbon-emitting energy forms, such as solar and nuclear power, for coal in electricity generation to control local and regional air pollution can affect GHG emissions as well. On the other hand, some policies that reduce local air pollution, such as scrubbing power plants for sulphur, can reduce power-plant efficiency and increase GHG emissions.

10.1.2.4 Uncertainty Is Pervasive

There are many uncertainties regarding the magnitude of future climate change, its consequences and the costs, benefits and implementation barriers of possible solutions. Future emissions to the atmosphere are inherently uncertain and can only be explored on the basis of scenarios. The change in concentration of GHGs that would result from a given emission rate is much less uncertain. But the timing, extent, and distribution of climate change and sea level rise for a given concentration of GHGs is not well known due to limitations in modelling climate change at the regional level. The impacts of climate change on ecosystems and humanity is known with limited certainty. The potential for an unspecified, low-probability, but catastrophic turn of events haunts the problem.

While uncertainties are great, they are not distributed evenly throughout the problem. The cost implications of emissions mitigation are better known than the more distant (in time) potential benefits from mitigation. In part this is because of temporal proximity, but it is also because most of the costs

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[2] See also, for example, Energy Innovations, 1997; Interlaboratory Working Group on Energy Efficient and Low-Carbon Technologies, 1997, 2000; Koomey *et al*., 1998; Bernow *et al*., 1999; Edmonds *et al*., 1999; Geller *et al*., 1999; Laitner, 1999; Laitner *et al*., 1999; PCAST, 1999; Hanson and Laitner, 2000; Kim *et al*., 2000.

associated with emissions mitigation pass through markets, whereas many of the benefits do not. Some uncertainties will remain unresolved regardless of the decisions made. This follows directly from the fact that there is only one observed history. All the other potential histories are counterfactual, and therefore constructs from analytical tools that are limited in their veracity. In decision making terms the problem of climate change mitigation requires decision making under uncertainty. Given the long lead times of mitigation action, fully resolving uncertainties would make an adequate response infeasible.

10.1.2.5 The Consequences Are Potentially Irreversible

Many global biogeochemical processes have long time scales. Sea level changes as a consequence of changes in mean global temperature can take more than 1000 years to play out. Similarly, changes in the concentration of GHGs can rise rapidly, but decline slowly. And, even if concentrations can be reduced, the nature of the climate system is such that it might not return to the same climatic state associated with an earlier concentration.

10.1.2.6. The Global Institutions Needed to Address the Issue Are only Partially Formed

The UNFCCC has been ratified by more than 170 parties and entered into force in 1994. It provides the institutional foundations upon which international climate change negotiations occur. It sets as its ultimate objective the stabilization of the concentration of GHGs in the atmosphere at levels that prevent dangerous anthropogenic interferences with the climate. However, the UNFCCC establishes a process and does not create the institutions for implementing the objective. The objective has not yet been quantified. The term “dangerous” is left open to interpretation by the parties.

The Kyoto Protocol of December 1997, described in Chapter 1, represents a further important step in the international regime formation under the UNFCCC. The Kyoto Protocol has brought a number of new elements and broadened the context of the decision-making process regarding implementation of climate change policy. Ultimately, further institutional development is needed for the UNFCCC to meet its final objective.

10.1.3. Tools of Analysis and their Summary in the Second Assessment Report

10.1.3.1 Tools of Analysis

A wide variety of tools have been applied to the climate problem. These are enumerated and briefly described in *Table 10.1*. In general, these tools help decision makers in several ways–choose a policy strategy, understand the implications of alternative policy strategies, understand the joint interactions of multiple, individual policy strategies. The tool can be employed by either a single decision maker or by stakeholder groups. Their quantitative nature and their ability to incorporate the global, long-term diversity of relevant human activities, the uncertainty, and the irreversibility characteristics of the problem mean that decision frameworks have been broadly applied to the climate problem. This approach has several special cases, which have themselves received broad attention, including cost–benefit analysis and cost-effectiveness analysis. We review progress in these areas later in this section, after the SAR and the “tolerable window and/or safe landing” (TWSL) work.

Other tools have also been employed or have the potential to be employed to help illuminate decision making. These include game theory, portfolio theory, public finance, culture theory, and simulation exercises, and are discussed in the body of the chapter.

10.1.3.2 Summary of the Second Assessment Report

SAR divided its discussion of DMFs into four sections–an introduction, a discussion of the context of decision making, a discussion of the tools for decision analysis, and concluded by considering the implications for national decision-making in the context of the UNFCCC. The chapter began by discussing the features of climate change that distinguish it from other environmental problems. It then described decision analysis and the present state-of-the-art.

Decision analysis uses quantitative techniques to identify the “best” choice from among a range of alternatives. Model-based decision analysis tools are often used as part of interactive techniques in which stakeholders structure problems and encode judgements explicitly in subjective-preference scales. It makes the major trade-offs explicit. Although decision analysis can generate an explicit value as a basis for choice, it is based on a range of relevant monetary and non-monetary criteria. It is used to explore the decision and to generate improved options that are well balanced in the major objectives and that are robust with respect to different futures. A review of the real world limitations of quantitative decision models and the consistency of their theoretical assumptions with climate change decision-making highlighted the following points:

- There is no single decision maker in climate change. As a result of differences in values and objectives, parties that participate in a collective decision-making process do not apply the same criteria to the choice of alternatives. Consequently, decision analysis cannot yield a universally preferred solution.
- Decision analysis requires a consistent utility valuation of decision outcomes. In climate change, many decision outcomes are difficult to value.
- Decision analysis may help keep the information content of the climate change problem within the cognitive limits of decision makers. Without the structure of decision analysis, climate change information becomes cognitively unmanageable, which limits the ability of decision makers to analyze the outcomes of alternative

Table 10.1: *Decision-making frameworks: compatibility with decision-making principles, and applicability at geopolitical levels and in climate policy domains*

Decision analysis frameworks	Description of the tool	Applicability to problem characteristics	Comment
Decision analysis	Decision analysis is a formal quantitative technique for identifying "best" choices from a range of alternatives. Decision analysis requires the development of explicit influence structures that specify a complete set of decision choices, possible outcomes, and outcome values. Uncertainty is incorporated directly in the analysis by assigning probabilities to individual outcomes.	G, L, H, U, IR	Virtues include quantification of results, reproducibility of analysis, ability to incorporate the full dimensionality of the climate problem explicitly. Limitations include the assumptions of: 1. A single decision-maker, with well-ordered preferences, who is expected to be present throughout the period of analysis. 2. The number of alternatives is finite and therefore limited in practice. 3. Outcomes must be comparable–implying the need for aggregation to a single set of common units, e.g. US$, lives, utility. 4. Rationality. 5. Uncertainties are quantifiable.
Cost–benefit analysis	Estimates of the costs and benefits for selected decision variables are derived. The "best" outcome is the one with the highest net benefits.	G, L, H, U, IR	1. This is a special case of general decision analysis. 2. Requires an explicit mechanism for valuing costs and benefits across time.
Cost-effectiveness analysis	Accepts specific performance goals as given exogenously, then minimizes the cost to achieve the desired performance.	G, L, H, U, IR	1. This is a special case of general decision analysis. 2. Requires an explicit mechanism for valuing costs and benefits across time. 3. Provides no information about the selection process. For example, analysis might accept a fixed CO_2 concentration ceiling as specified exogenously, but cannot comment on the desirability of that choice.
Tolerable windows and/or Safe landing approach	Accepts specific performance goals as inequalities given exogenously, then enumerates paths that are consistent with the goals.	G, L, H, U, IR	1. Provides no information about the selection process. For example, analysis might accept a fixed CO_2 concentration ceiling as specified exogenously, but cannot comment on the desirability of that choice. 2. The analysis does not provide a "best" path.
Game theory	Provides information about the implication of multiple decision-makers' choices, taking into account expectations that each has of their own actions on others, and others' actions on them.	G, IN	Technique is descriptive rather than prescriptive. It offers information about potential outcomes within a specific context.

(continued)

Table 10.1: *continued*

Decision analysis frameworks	**Description of the tool**	**Applicability to problem characteristics**	**Comment**
Portfolio theory	Concerned with creating under a budget constraint an optimal composition of assets characterized by different returns and different levels of risks. Decision options (portfolio elements) are represented by a probability distribution of expected returns while risks are estimated on the basis of the variability of expected returns, and only these two factors determine the decision makers' utility function. The decision rule is to choose the efficient portfolio compared to which no other portfolio offers higher expected return at the same or lower level of risk or lower risk with the same (or higher) expected return.	G, L, H, IN	Application to climate change problem has been limited.
Public finance theory	Encompasses a variety of research techniques including the theory of the second best.	IN	Examines trade-offs between efficiency and other criteria.
Ethical and cultural prescriptive rules	Concerned primarily with the implications of alternative social organizations. Has had limited application to the climate problem.	IN	1. Used to consider explicitly the interactions between policy instrument choice and social structure. 2. It is non-quantitative.
Policy exercises, focus groups, and simulation gaming	Includes a suite of research activities that have been used to assist in the decision-making process. In general, groups examine potential outcomes by playing a role in a simulated decision-making environment.	G, IN	1. Results are generally not reproducible. 2. Computer models may be used to assist in the exercise. 3. Much of the value is pedagogical.

Notes: G = global; LT = long-term; H = pervasive human activities; U = uncertainty; IR = irreversible; IN = relevant to institutional framing.

actions rationally. Quantitative comparisons among decision options (and their attributes) are implied by choices between options (the concept of "revealed preference" in economics). Better decisions are made when these quantitative comparisons are explicit rather than implicit.
- The treatment of uncertainty in decision analysis is quite powerful, but the probabilities of uncertain decision outcomes must be quantifiable. In climate change, objective probabilities have not been established for many of the outcomes. In real-world applications subjective probabilities are used.
- The large uncertainties and differences between parties may mean there can be no "globally" optimal climate-change strategy; nevertheless, the factors that affect the optimal strategies for single decision makers still have relevance to individual parties.

The lack of an individual decision maker, utility problems, and incomplete information suggest that decision analysis cannot replace the political process for international climate-change decision-making. Although elements of the technique have considerable value in framing the decision problem and identifying its critical features, decision analysis cannot identify globally optimal choices for climate change abatement. Decision analysis suffers fewer problems when used by individual countries to identify optimal national policies.

The UNFCCC establishes a collective decision-making process within which the parties negotiate future actions. Although some features of the decision-making process are set out in the Convention, many are still undecided. It becomes important, then, to examine negotiation and compromise as the primary basis for climate change decisions under the Convention. Important factors that affect negotiated decisions include the following:
- Excessive knowledge requirements in negotiated environmental decisions may impede a collective rational choice. This difficulty could be reduced by making the negotiation process itself more manageable through the use of tools like stakeholder analysis or by splitting accords into more easily managed clusters of agreements.
- In the face of long-term uncertainties, sequential decision-making allows actions to be better matched to outcomes by incorporating additional information over time. Sequential decision-making also minimizes harmful strategic behaviour among multiple decision makers.
- Improved information about uncertain outcomes may have very high economic value, especially if that information can create future decision options.
- There are currently no effective mechanisms for sharing the risks related to climate change and their associated economic burdens. International risk sharing could yield substantial benefits for global economic and social welfare.

The Convention is, first and foremost, a framework for collective decision making by sovereign states. Given this collective decision mechanism and the uncertainties inherent in the climate problem, several recommendations emerge:
- decisions for actions under the UNFCCC are rather being taken sequentially to benefit from the gradual reduction in uncertainties;
- countries may implement a portfolio of mitigation, adaptation, and research measures;
- they may adjust this portfolio continuously in response to new knowledge (the value of better information is potentially very large); and
- efficient distribution of the risks of losses related to climate change may warrant new insurance mechanisms.

10.1.4 Progress since the Second Assessment Report on Decision Analytical Frameworks

Much work has been conducted since SAR. Work has focused on a wide array of issues ranging from that which explores the tools of analysis to that which employs those tools to shed light on the problem of climate change. Researchers such as De Canio (1997), De Canio and Laitner (1997), De Canio *et al*. (2000a, 2000b, 2000c), Laitner and Hogan (2000), Laitner *et al*. (2000), Peters and Brassel (2000), and Sanstad *et al*. (2000a, 2000b) have focused on integrated assessment, endogenous technological change, and behavioural, social, and organizational phenomena (discussed in Chapter 8). Work has also continued to examine the problems of cost–benefit, cost-effectiveness, and the interaction of uncertainty with decision making. New approaches have also been developed, including, for example, tolerable windows and safe landing.

10.1.4.1 Decision-making under Uncertainty

Work has continued in the development of tools to understand the influence of uncertainty on decision making. The initial work examined in SAR explores the problem of emissions-mitigation objectives under a cost-effectiveness framework, but the interaction between concentration limits and the date at which uncertainty is resolved influences the results. This interaction occurs because in decision analysis no option can ever be foreclosed before the date at which uncertainty is hypothesized to be resolved. Any concentration ceiling implies a cumulative emissions limit. Thus preserving the option to stay below any arbitrary limit means adopting a hedging strategy. Grubb (1997) characterizes the problem thus: "If we delay action in the belief that we are aiming at a 500ppmv target, for example, then after a couple of decades it may be simply too late to be able to stabilize at 400ppmv, however urgent the problem then turns out to be; and even stabilization at 450ppmv might by then involve radical changes of direction that could prove economically very disruptive."

The core of the issue is the interplay between inertia and uncertainty; without inertia any trajectory could indeed be corrected at no cost, but as inertia is important, changing course may be very costly. Fortunately, the Convention embodies the dynamic nature of the decision problem in drafting climate as an ongoing process, not a “once and for all” event. The UNFCCC (1993) requires periodic reviews “in light of the best scientific information on climate change and its impacts, as well as relevant technical, social and economic information.”

Such a sequential decision-making process aims to identify short-term strategies in the face of long-term uncertainties. The next several decades will offer many opportunities for learning and mid-course corrections. The relevant question is not “what is the best course of action for the next 100 years”, but rather “what is the best course for the near-term given the long-term objective?”

There have been several attempts to frame the issue. *Figure 10.1* reports the results of an analysis by Ha-Duong *et al*. (1997). The authors use their model of the Dynamics of Inertia and Adaptability for integrated assessment of climate-change Mitigation (DIAM) to determine the least-cost emission pathway given an uncertain concentration target. A defining feature of their model is an inertia parameter that accounts for the time scale of change in the global energy system. In their analysis they assign equal probability to a target of 450, 550, and 650ppmv. The solid 550ppmv line corresponds to the optimal pathway when the target is known to be 550ppmv from the outset. The analysis shows the optimal hedging strategy when uncertainty is not resolved until 2020. The authors note that “our results show that abatement over the next few years is economically valuable if there is a significant probability of having to stay below ceilings that would be otherwise reached within the characteristic time scales of the systems producing greenhouse gases.”

The degree of near-term hedging in the above analysis is sensitive to the date of resolution of uncertainty, the inertia in the energy system, and assumes that the ultimate concentration target (once it has been agreed) must be met at all costs. The last stems directly from the formulation of the problem as one of finding the least-cost mitigation pathway in the face of uncertainty. Since a future political decision on a 450ppmv target cannot be excluded, decisions prior to 2020 must be such that they do not preclude the achievement of such a target.

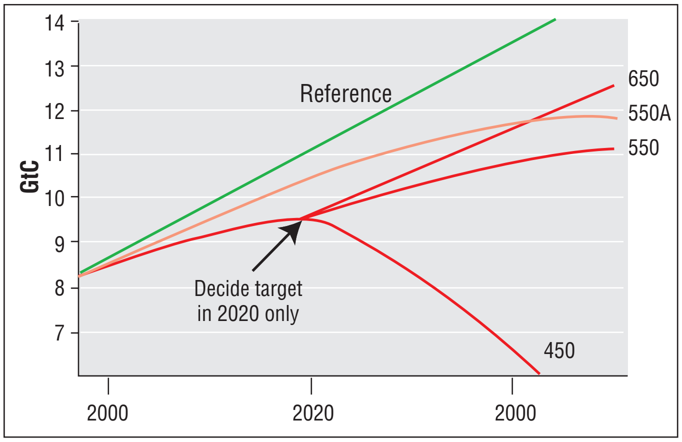

Figure 10.1: *Optimal carbon dioxide emissions strategy, using a cost-effectiveness approach.*

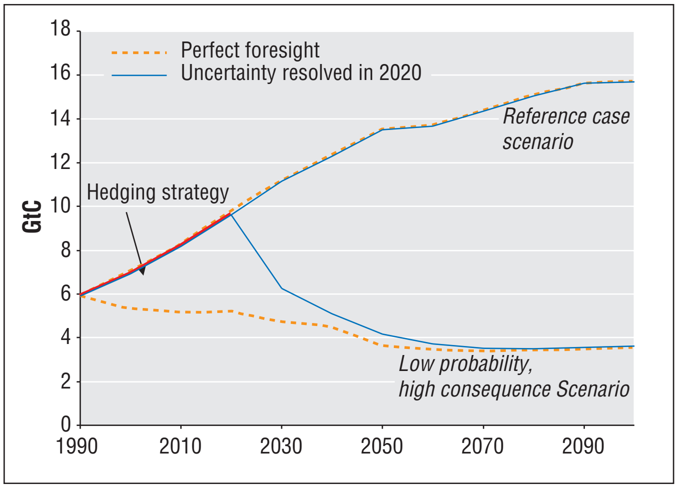

Figure 10.2: *Optimal hedging strategy for low probability, high consequence scenario using a cost-benefits optimization approach.*

One way to avoid the bias inherent in the framing of the emissions control problem under uncertainty is to reframe the problem as a decision tree structure within the context of cost–benefit analysis rather than cost-effectiveness analysis. This was the approach taken by the seven models used in an Energy Modeling Forum (EMF; Manne, 1995) exercise on climate change decision making under uncertainty (Weyant, 1997). The study focused on hedging strategies for low probability, high consequence scenarios in which uncertainty was not resolved until 2020. Two parameters were varied: the mean temperature sensitivity factor and the cost of damages associated with global warming. The unfavourable cases were defined as the top 5% of each of these two distributions. Two surveys of expert opinion were used to choose the distribution of these variables. For the opinion survey on climate sensitivity, see Morgan and Keith (1995), and for warming damages, see Nordhaus (1994b). *Figure 10.2* (Manne and Richels, 1995; Manne 1995) shows what happens when the unfavourable case has a probability of 0.5 and the expected case a probability of 0.95 (the two parameter values assumed for the unfavourable case are shown in the surveys cited above as being in the upper 5% of each of the distributions of the two key parameters, i.e., climate sensitivity and climate damages). The dashed lines show what happens if perfect foresight is available and can make today’s decisions in the full knowledge of which of these outcomes will occur. The solid lines indicate the average results from an economically efficient hedging strategy. The analysis takes into account both the costs and benefits of emissions abatement. With a cost-benefit analysis, costs and benefits are balanced at the margin. Seven EMF modelling teams have confirmed these results (Weyant, 1997). The reason for so little hedging is the low probability of the extreme outcome, that is 0.25%. If one were to increases this probability, the desired degree of hedging would increase accordingly.

Another parameter for stochastic cost–benefit analysis is the importance of non-linearity in the impacts and the date at which some threshold is likely to occur. Peck and Tiesberg (1993) observed that optimal policies were more sensitive to uncertainty in the damage-function power parameter than to uncertainty in the scale parameter. Ha-Duong *et al*. (1999) confirm this view and demonstrate that introducing thresholds in the damage function leads to more significant decoupling from current emissions trends for a given probability distribution.

Ultimately, as recognized in the IPCC (1996c) one should try and assess the option value of the information incorporated in alternative emissions pathways, that is the capacity of society to adapt to any new information. As pointed out by Ulph and Ulph (1997), the environmental irreversibility has to be balanced against the technological irreversibility, including the crowding out between forms of technical progress. Ha-Duong (1998) finds, comparing Working Group I (WGI) and Wigley, Richels, Edmonds (WRE) strategies, that the magnitude of the value of information is significant compared with the opportunity costs of abatement. On the basis of nine scenarios he found that the information value of acting soon is, for most of them, higher than that of acting later, if low and high damages are assumed equally probable.

Whatever the approach, the basic message is quite similar. First the costs and benefits of quick action have to be balanced against those of delayed action; second, to assume that the concentration target is known with certainty is an over-simplification of the decision problem. What is needed is an approach that explicitly incorporates uncertainty and its sequential resolution over time. The desirable amount of hedging should depend upon assessment of the stakes, the odds, and the costs of policy measures. The risk premium – the amount that society is willing to pay to reduce risk – ultimately is a political decision that differs among countries.

Uncertainty also affects the choice of policy instrument. In principle many mechanisms can be employed to limit emissions, including, voluntary agreements among domestic and international parties, regulation, taxes, subsidies, and quotas or tradable permits (see Chapter 6). Economists have focused on the potential role of taxes and quotas because these tools hold potential for cost minimization. Although both instruments are equivalent in a world with complete information (the optimal quota leads to the same marginal abatement cost as the optimal tax level), Pizer (1999), building upon a seminal work by Weizman (1974), demonstrated that this is not the case if uncertainties about climate damage and GHG abatement costs are considered.

Indeed, welfare losses that result from imperfect foresight depend on whether the steepness of the marginal abatement cost curve is higher or lower than that of the damage curve. Hence the finding that a co-ordination through price is preferable as long as the probability of dramatic non-linearity in climate systems is not large over the middle term. This policy conclusion can be reverted if the transaction costs of adopting co-ordinated taxation, high level of risk-aversion to catastrophic events, or a large amount of "no regrets" policies are considered. The main message, however, is that in a tax co-ordination approach costs are observable (while the outcome is not predictable), but in a quota approach the outcome is observable although there is an uncertainty about the resultant costs. In this respect, emissions trading is logically a companion tool for a system of emissions quotas, to hedge against the distributional implications of surprises regarding abatement costs and emissions baselines.

10.1.4.2 Cost-effectiveness Analysis

There is an increased interest in cost-minimizing paths that lead to alternative, stable steady-state concentrations of GHGs in the atmosphere. This interest stems from the objective of the UNFCCC–to stabilize the concentration of GHGs. Work has focused primarily on the problem of stabilizing the concentration of CO_2. The focus on CO_2 reflects the importance placed on this gas by the Intergovernmental Panel on Climate Change Working Group I (IPCC WGI) and the distinctive characteristic of CO_2. As CO_2 does not have an atmospheric sink, the net emissions to the atmosphere must eventually decline indefinitely to maintain any steady-state concentration (IPCC, 1996a). In contrast, GHGs such as CH_4 and N_2O, with atmospheric sinks, have steady-state concentrations associated with steady-state emissions. Cost-effective paths depend on many factors including reference emissions, technical options for emissions limitation, the timing and rate of change of the availability of options, the discount rate, and assumed control mechanisms and their efficiency. The analysis conducted to date generally does not take into account that long-term emissions mitigation must take place against a background of climate change that affects both the nature and composition of economic activity and the carbon cycle.

Both Manne and Richels (1997) and Edmonds *et al*. (1997) examined the relationship between steady-state concentrations of CO_2 and associated minimum costs. Both papers computed the minimum cost of honouring a concentration ceiling. All cost calculations assumed that all activities throughout the world pursued emissions mitigation based on a common marginal cost of carbon emissions mitigation. While real-world implementation strategies are likely to be less efficient, the choice of a cost-effective assumption for each period provides a unique benchmark for comparison purposes. Several assumptions regarding cost-effectiveness over time were examined. The two studies examined three cases:

- global emissions limited to a trajectory prescribed by IPCC (1995), labelled WGI;
- global emissions limited to a trajectory prescribed by Wigley *et al.* (1996), labelled WRE; and
- a model-determined minimum-cost emissions path.

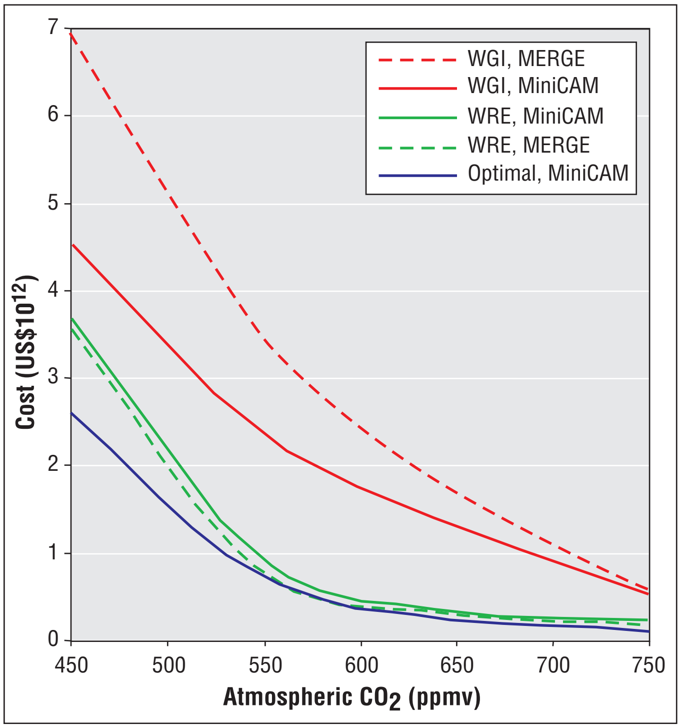

Figure 10.3: *Relationship between present discounted costs for stabilizing the concentration of carbon dioxide in the atmosphere at alternative levels from two studies. Costs are discounted at 5%/yr over the time period 1990 to 2100. Sources: Manne and Richels (1997) and Edmonds et al. (1997).*

Costs were discounted over time at 5%/yr over the period 1990 to 2100. The results are displayed in *Figure 10.3*.

Costs are roughly an order of magnitude greater for concentration ceilings of 450ppmv than for the 750ppmv ceiling between WGI, WRE, and optimal global emissions constraints. Furthermore, costs decline sharply as the constraint is relaxed from 450ppmv to 550ppmv. Relaxation of the constraint from 650ppmv to 750ppmv reduces costs, but at a more modest rate. As discussed in Chapters 2, 7 and 8, it should be noted that the total costs of stabilizing atmospheric carbon concentrations are very dependent on the baseline scenario: for example, for scenarios focusing on the local and regional aspects of sustainable development costs are lower than for other scenarios.

Progress has also been made in examining the time path of the value of a tonne of carbon when the cost of stabilizing the concentration of CO_2 is minimized. Peck and Wan (1996) demonstrated that the results of Hotelling (1931) could be applied to the problem of minimizing the cost to stabilize the concentration of CO_2 and generalized. They show that to minimize present discounted cost, the value of a tonne of carbon should rise at the rate of interest (discount rate). This theorem ensures that the marginal cost of emissions mitigation across both space and time is equal after taking into account that carbon is naturally removed from the system. Thus, the initial marginal costs should be relatively modest, but should rise steadily (at the rate of interest plus the rate of carbon removal, approximately 1%/yr). The rise in marginal cost continues until it reaches the marginal cost of a “backstop” technology, one capable of providing effectively unlimited emissions mitigation at a constant marginal cost.

All cost-effective policies minimize the cost of stabilization by equalizing the marginal cost of mitigation across time and space, that is, in all regions, across all human activities, and across all generations, except to the extent that non-linearities, non-convexities, and corner solutions exist. The implementation of real-world regimes to control net emissions to the atmosphere is likely to be inefficient to some degree for a number of reasons, including, for example, the problems of “free riding”; cheating; in some cases considerations of fairness and equity; and monitoring, compliance, and transactions costs.

Some work has been undertaken to compare potential policy regimes with respect to cost-effectiveness. For example, Chapter 8 shows the difference in emissions mitigation requirements between various potential implementations of the Kyoto Protocol and more cost-effective paths. Edmonds and Wise (1998) examined the cost effectiveness of a strategy that sought to minimize the costs of monitoring and verification, and premature retirement of capital stocks, while simultaneously addressing concerns about fairness and equity. They considered a hypothetical protocol that focused on new investments in energy technology. They assumed that Annex I nations required new emissions sources to be carbon-neutral after a prescribed date. Existing sources were treated as new after a fixed period following their initial deployment. Non-Annex I nations remained unencumbered until their incomes reached levels comparable to those in Annex I nations. The authors concluded that the regulatory regime could stabilize the concentration of GHGs, and that the level at which concentrations stabilized is determined by the initial date of obligations. The hypothetical protocol is economically inefficient, however. That is, it does not minimize the cost of achieving a concentration limit. The authors compare the hypothetical protocol, which uses a technology regulation to limit emissions, with an alternative cap-and-trade regime that achieved the same emissions path. Costs in the hypothetical protocol were approximately 30% greater than in those in the alternative cap-and-trade regime.

Jacoby *et al*. (1998) also considered the problem of accession to the Kyoto Protocol. They reject the idea that there is such a thing as inter-temporal cost-effectiveness in the context of a century-scale problem. Rather, they begin with the proposition that a continuous process of negotiation and re-negotiation is required. They analyze a system of obligations based on per-capita income that can lead to the stabilization of concentrations of GHGs.

A substantial body of work has considered the implication of technology development and deployment on the cost of meeting alternative emissions-mitigation obligations. This line of investigation has a long tradition extending back to, for example, Cheng *et al*. (1985). These are discussed in Chapter 8[3]. Recent studies, for example by Dooley *et al*. (1999), Edmonds and Wise (1999), Grübler *et al*. (1999), PCAST (1999), Schock *et al*. (1999), and Weyant and Olavson (1999), have explored the potential role of a variety of technologies in both the near term and the longer term. The principal conclusion of this body of investigation is that the cost of emissions mitigation depends crucially on the ability to develop and deploy new technology. The value of successful technology deployment appears to be large with the value depending on the magnitude and timing of emissions mitigation and on anticipated reference scenario progress.

10.1.4.3 Tolerable Windows and Safe Landing Approaches

Considerable work since the SAR has explored the implications for global emissions of GHGs of a set of constraints on a variety of associated phenomena. This vein of research is referred to as the tolerable windows and/or safe landing (TWSL) approach. See, for example, Alcamo and Kreileman (1996a, 1996b) and Swart *et al*. (1998) for early work on the safe landing approach and Toth *et al*. (1997) for early work on the tolerable windows approach. The approach seeks to limit the emissions time-paths with implications for the near term and long term. While the tolerable windows and safe landing analyses differ somewhat in the detail of their implementation, they are similar in approach. We consider the safe landing approach first. In a multimodel exercise four constraints on emissions trajectories are considered: temperature change since 1990, maximum decadal rate of temperature change, sea level rise between 1990 and 2100, and maximum rate of sea level change. In addition, a limit on the rate of reduction of emissions is set.

Criteria	*Low*	*Medium*	*High*
Change in temperature from 1990	1.0°C	1.5°C	2.0°C
Decadal change in temperature	0.10°C	0.15°C	0.20°C
Change in sea level	20cm	30cm	40cm
Decadal change in sea level	2cm	3cm	4cm
Maximum reduction in emissions	2%	3%	4%

The safe landing interval is the range of emissions, given in CO_2 equivalent emissions (C_{eq}), in 2010. This range is 7.6–11.9GtC$_{eq}$; 1990 emissions were 7.10GtC, and approximately 9.8GtC$_{eq}$, equivalent, defined in terms of CO_2, CH_4, and N_2O only (Pitcher, 1999). Emissions for Annex I nations can be derived by subtracting the anticipated non-Annex I emissions from the global total.

Results from the analysis depend strongly on the constraints and model sensitivities. The tolerable windows approach (Toth *et al*., 1997, 1999; Bruckner *et al*., 1999; Petschel-Held *et al*., 1999) is formulated as a type of extended and generalized cost–benefit analysis for which two kinds of normative inputs are required. First, with the help of climate-impact response functions that depict reactions of climate-sensitive socioeconomic and natural systems to climate change forcing, social actors can specify their willingness to accept a certain amount of climate change in their own jurisdiction. Second, the same social actors reveal their willingness to pay for climate change mitigation in terms of acceptable burden-sharing principles and implementation schemes internationally, as well as in terms of tolerable utility, consumption, or Gross Domestic Product (GDP) loss in their own jurisdiction. An integrated climate-economy model (e.g., Integrated Assessment of Climate Protection Strategies - ICLIPS) can then determine whether there exists a corridor of emission paths over time that keeps the climate system within the permitted domain.

If the corridor does not exist, a willingness to accept more climate change can be specified (e.g., as a result of resource transfers to increase the adaptive capacity in the most constraining region or sector on the impact side). Alternatively, willingness to pay for emission reductions can be increased or more cost-reducing flexibility instruments can be allowed on the mitigation side. If the corridor does exist, it can be perceived as the room to manoeuvre for global climate policy over the long term. The tolerable windows approach leaves the specification of climate-change mitigation regimes up to decision makers involved in climate-change policy making at the global and national levels. The primary goal of the ICLIPS integrated assessment model (IAM) is to determine the implications of different equity principles in burden sharing and of various implementation mechanisms on the existence and shape of the emission corridor. Nevertheless, the model can also produce cost-effective emission paths.

The German Advisory Council on Global Change (WBGU) proposed two climate change constraints based on geohistorical arguments: the tolerable magnitude of climate change is set to 2°C compared to the pre-industrial era[4] and the rate of temperature increase should not exceed 0.2 °C per decade. On the cost side, it is assumed that to reduce GHG emissions at a rate faster than 4%/yr would be economically too painful to implement. These constraints are used to illustrate the application of the tolerable windows approach. The results presented here are based on an extended atmospheric chemistry–climate model. In addition to CO_2, the model also includes CH_4, N_2O, chloro-

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[3] See also Edmonds *et al*. (1994, 1996, 1997, 1999), Grübler and Nakicenovic (1994), Christiansson (1995), Shukla (1995), Goulder (1996), Energy Innovations (1997), Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies (1997, 2000), Mattsson (1997), Grübler and Messner (1998), Koomey *et al*. (1998), Yamaji (1998), Bernow *et al*. (1999), Geller *et al*. (1999), Laitner (1999), Laitner *et al*. (1999), Lako *et al*. (1999), Hanson and Laitner (2000), and Kim *et al*. (2000).

[4] This 2 degree centigrade limit has also been adopted by the European Union as its provisional target for stabilizing greenhouse gas concentrations in the atmosphere under UNFCCC Article 2.

fluorocarbons (CFCs), and aerosols. One simplifying assumption is that all GHG emissions are reduced at the same rate, except for CFCs, which follow the IPCC IS92a scenario paths. For simplicity, energy-related global CO_2 emissions are presented in *Figure 10.4*.

Figure 10.4(a) presents the basic emission corridor for the WBGU window. It follows from the mathematical formulation of the model that at least one permitted emission path passes through any arbitrary point in the corridor. However, not every arbitrary path within the corridor is necessarily a permitted path. If emissions follow the upper boundary of the corridor in the first few decades after 1995, for example, this would entail a sharp turnaround and persistent emission reductions at the maximum annual rate (4%/yr) for many decades to come.

How do near-term emissions affect the available flexibility over the long-term? The scenario presented in *Figure 10.4(b)* shows this. Here it is assumed simply that CO_2 emissions follow the baseline path according to the IPCC IS92a scenario until 2010. The result is a much narrower corridor: it implies that the likelihood of a fast turnaround of emissions and persistent reductions at relatively higher rates (3%–4%/yr) is significantly higher.

The next analysis illustrates the implications of a fairness principle for the Annex I emission corridor. The assumption is that GHG emissions by non-Annex I countries follow the baseline path and these countries start emission reductions only when their per capita emissions reach those of Annex I levels on the basis of their 1992 populations. The resultant Annex I corridor is presented in *Figure 10.4(c)*. Obviously, the result is a relatively narrow corridor.

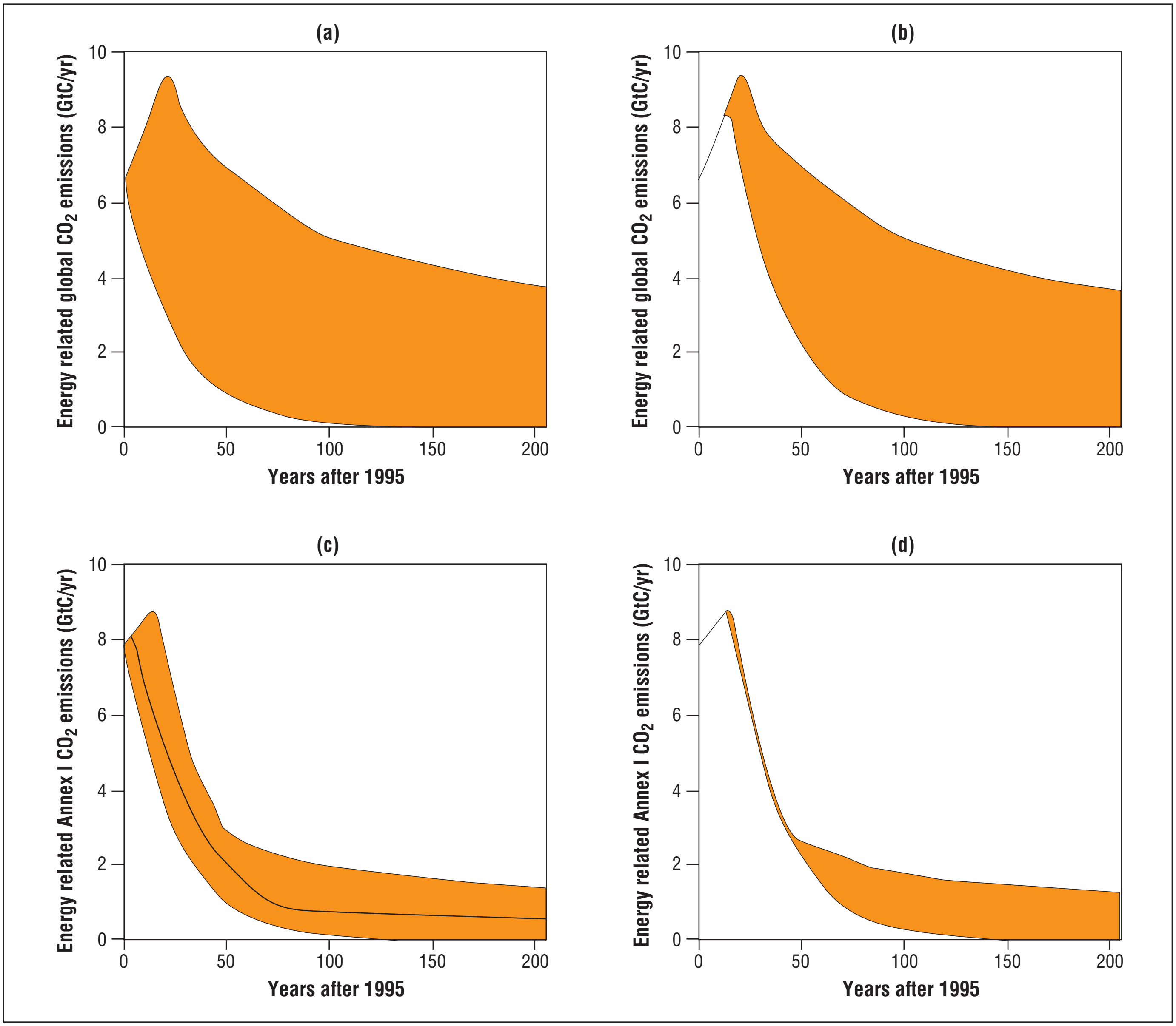

Figure 10.4: *Emission corridors under different assumptions on delaying reduction measures and equity principles.*

Figure 10.4(d) shows the resultant emission corridor if the above two assumptions about future emissions are combined. This implies that the world community follows the baseline emission path until 2010 and reduction obligations will be distributed between the Annex I and non-Annex I countries according to the case in *Figure 10.4 (c)*. The result for Annex I countries emissions through the first half of the 21st century looks like a straightjacket rather than an emission corridor with ample choice.

Importantly, Annex I corridors in *Figures 10.4(c)* and *10.4(d)* reflect the rigid implementation of emission quotas that result from the specified equity principle. No cost divergence is considered between Annex I and non-Annex I. The difference between *Figures 10.4(a)* and *10.4(c)* corridors indicates the potential to reduce abatement costs if Annex I countries are allowed to "buy" part of the non-Annex I corridor. The economic value of this transaction is the subject of many detailed energy-economy models (see Section 10.4).

It is clear that all these emission corridors are associated with the global climate window as specified by the Council. It is beyond the scope of this analysis to discuss arguments for and against whether the 2°C increase in global mean temperature above the pre-industrial level and the rate of temperature increase at no more than 0.2°C per decade are preferred or realistic propositions. The objective for the tolerable windows approach is to provide an assessment framework that can help test any climate protection proposal formulated through selected climate attributes. The computed emission corridors, nevertheless, can assist in deciding the magnitude and urgency of the policy measures associated with them, and/or trigger rethinking the originally proposed climate change targets. The presented example also shows how equity concerns can be analyzed in the tolerable windows approach, albeit in a terse form.

10.1.4.4 Computational, Multiscenario Simulation Approaches

Computational, multiscenario simulation is a new analytic approach to the assessment of climate change policy. Bankes (1993), Lempert *et al*. (1996), and Laitner and Hogan (2000) have employed this approach, as have Morgan and Dowlatabadi (1996), van Asselt and Rotmans (1997), and, to some extent, Yohe (1996). Also, the IPCC Special Report on Emissions Scenarios (IPCC, 2000b) presented a large set of very different baseline scenarios. The basic idea is to use computer simulation models to construct a range of a large number of fundamentally different scenarios of the future and, instead of aggregating the results using a probabilistic weighting, make policy arguments from comparisons of fundamentally different, alternative cases. These methods are most useful under conditions of deep uncertainty. For example, when we do not have reliable information or widespread agreement among the stakeholders about the system model, the prior probability distributions on the parameters of the system model, and/or the loss function to use in evaluating alternative outcomes (Lempert and Schlesinger, 2000).

These multiscenario simulation approaches offer the promise of a powerful synthesis between the narrative, process-oriented methods of scenario-based planning (Schwartz, 1996; van der Heijden, 1996) and quantitative tools such as decision analysis, game theory, and portfolio analysis. From the quantitative methods, multiscenario simulation draws systematic methods of handling large quantities of data and normative descriptions of good decisions. From scenario-planning, multiscenario simulation draws the insight that multiple views of the future are crucial to allow groups to transmit and receive information about highly uncertain futures. Also scenario planning shows that groups can often agree on actions to take in the face of deep uncertainty without agreeing on the reasons for these actions (Lempert and Schlesinger, 2000). For instance, multiscenario simulation can adopt a meaningful cost–benefit framework for climate change, but at the same time acknowledge the deep uncertainty and differing values among stakeholders. These make it impossible to fully quantify the costs and benefits or to assign widely accepted probabilities to many of the key outcomes of interest. Such computational, multiscenario simulations are enabled by new computer technology–primarily large quantities of inexpensive memory; fast, networked processors; and powerful visualization tools–and are only just becoming available.

10.1.5 Robust Decision-making

Uncertainty is a feature that pervades discussions on climate change issues. IPCC SAR covered main areas of uncertainties, especially those related to:

- atmospheric concentrations of GHGs and their impact on meteorological phenomena (IPCC, 1996a);
- the potential of technological options and the relationships between climate change and the dynamics of natural systems (IPCC, 1996b); and
- socio-economic dimensions of climate change (IPCC, 1996c).

Several sections in this report (1.5; 2.2; 7.2; 10.1) review new and complementary perspectives that facilitate a better understanding of the tensions between the limited capacity to predict and the urgent need to act in a situation faced with high stakes of risk.

The implications of uncertainty are global in scale and long-term in their impact; quantitative data for baselines and the consequences of climate change are inadequate for decision making. In recent years, researchers and policymakers have become increasingly concerned about the high levels of inherent uncertainty, and the potentially severe consequences of decisions that have to be made.

Conventional frameworks for decision making on climate change policies presume that relevant aspects of the contextual environment are to some extent predictable; therefore uncertainty can be reduced to provide decision makers with appropriate information within appropriate time frames.

This *anticipatory management approach* is based on the premise that it is possible to predict and anticipate the consequences of decisions and hence to make a proper decision once all the necessary information is gathered to make a scientific forecast. The prevailing image is that "given enough information and powerful enough computers it is possible to predict with certainty, in a quantitative form, which in turn makes it possible to control natural systems" (Tognetti, 1999).

Anticipatory approaches have successfully managed a wide range of decision problems in which the relative uncertainties are reducible, and the stakes or outcomes associated with the decisions to be made are modest (Kay *et al*., 1999). A number of uncertainty analysis techniques, such as Monte Carlo sampling, Bayesian methods, and fuzzy set theory, have been designed to perform sensitivity and uncertainty analysis related to the quality and appropriateness of the data used as inputs to models. However, these techniques, suitable for addressing technical uncertainties, ignore those uncertainties that arise from an incomplete analysis of the climate change phenomena, or from numerical approximations used in their mathematical representations (modelling uncertainties), as well as uncertainties that arise from omissions through lack of knowledge (epistemological uncertainties). Current methods thus give decision makers limited information regarding the magnitude and sources of the underlying uncertainties and fail to provide them with straightforward information as input to the decision-making process (Rotmans and de Vries, 1997).

The management of uncertainties is not just an academic issue but an urgent task for climate change policy formulation and action. Various vested interests may inhibit, delay, or distort public debate with the result that "procrastination is as real a policy option as any other, and indeed one that is traditionally favoured in bureaucracies; and inadequate information is the best excuse for delay" (Funtowicz and Ravetz, 1990).

Funtowicz and Ravetz have proposed a highly articulated and operational scheme for dealing with the problems of uncertainty and quality of scientific information in the policy context. By displaying qualifying categories of the information–numeral, unit, spread, assessment, and pedigree (NUSAP)–the NUSAP scheme provides a framework for the inquiry and elicitation required to evaluate information quality. By such means it is possible to convey alternative interpretations of the meaning and quality of crucial quantitative information with greater quality and coherence, and thus reduce distortion of its meaning.

In recent years a good deal of analytical work has addressed problem-solving strategies for different circumstances characterized by the inherent uncertainties in the situation and the severity of consequences that arise from the decision to be made. Adaptive management approaches to decision making start by accepting uncertainty as an inherent property of complex systems. The issue here is not the problem of a "deterministic version of scientific uncertainty"—a temporary matter of imprecision which will be eradicated when enough research has been devoted to the questions (Wynne, 1994). The starting point is the acknowledgement that uncertainty emerges not only from the long time-scales involved and/or the ability of models to predict long-term events, but mainly from the endemic uncertainty, indeterminacy, and ignorance related to the co-evolution of natural and social systems. Furthermore, these methods stress the relevance of values, ethical and social, and thus introduce the need for public discourse and debate (Westra, 1997).

A central concern in adaptive approaches is with the plurality of value systems and how multiple perspectives can inform the decision process. Various attempts have been made to incorporate a variety of perspectives in relation to uncertainty and to make uncertainty more explicit by expressing it in terms of risk.

Parallel modelling (Visser *et al*., 2000) and computational, multiscenario simulation (Lempert *et al*., 1996; Morgan and Dowlatabadi, 1996; van Asselt and Rotmans, 1997) are emerging approaches based on the idea that multiple views of the future are crucial to allow groups to transmit and receive information about highly uncertain futures.

Rather than aggregate different scenario or model results using probabilistic weights or using computer resources to increase the resolution of a single best-estimate model, analysts use simulation models to construct different scenarios to compare different, alternative policy options based on their robustness across the scenarios. Valuation is thus reframed as a process in which uncertainty is not banished, but is managed, and values are not presupposed but are made explicit.

The analysis of multiple and diverse perspectives as a source of uncertainty has been addressed by van Asselt and Rotmans (1997) within the framework of the Tool to Assess Regional and Global Environmental and health Targets for Sustainability (TARGETS) IAM. The authors introduce the idea of model routes–a chain of biased interpretations of the crucial uncertainties in the model–to analyze differences in future projections as the outcome of divergent views and valuations, instead of merely of low, high, and medium values. The approach distinguishes two dimensions of perspectives: (1) a world view, which entails a coherent view of how the world functions, and (2) a management style, that is policy preferences and strategies. By combining stereotypical views of nature and humanity as well as ethical attitudes with different management styles, the approach enables the analysis of "utopias" that result when views match the strategies and "dystopias" that result when they do not.

Dystopias are useful with respect to communicating the role of uncertainty and its consequences for decision making. They indicate the risk of decision making in uncertain conditions by showing to what kind of future the chosen strategies might lead, in the event that the adopted worldview fails to describe the reality adequately.

Another promising avenue for managing uncertainties is the exploratory modelling methods (Lempert *et al*., 1996; Lempert *et al*., 2000; Lempert and Schlesinger, 2000; and Robalino and Lempert, 2000) is discussed in Section 10.1.4.1.

Robustness is not a new concept, but it is just recently, under the pressure of global environmental problems and the acceleration of change, that such approaches have grown in formalization and sophistication (Rosenhead, 1990). Rooted in Savage's maximizing the minimum regret (1954), Simon's ideas of satisfying strategies (1959 a and b), and Lindbolm's incremental policies (1959), the search for robust strategies as a formal decision-making criterion has grown during the 1990s. However, it has always been more difficult to implement robustness, as opposed to optimization, within an analytical method, except for in very special cases. A new development over the past few years is that it is now becoming possible to implement robustness as an analytical criterion using simulation models of the type relevant to climate change policy. In conclusion, multiscenario simulation approaches, like multiple-model routes, exploratory models, or parallel modelling, show that uncertainty is no longer a theoretical scientific concept, but a notion that might be usefully deployed by decision makers in arriving at their decisions (van Asselt and Rotmans, 1997).

This ability to analytically address robustness is closely tied to the idea of adaptive decision strategies, that is, strategies that can change over time in response to observations of the climate and economic systems. (Adaptive decision strategies differ from sequential strategies in that in the former information is endogenous, that is, the type, rate, and quality of information gained depends on both the unfolding scenario and policy choices whereas information is exogenous in the sequential strategies.) Adaptive decision strategies are closely tied to the concept of robustness, because such strategies are most useful in situations of deep uncertainty–where robustness, as opposed to optimization, appears to be the best decision-making criterion.

10.2 International Regimes and Policy Options

10.2.1 Introduction

Previous chapters provide some answers to the most relevant policy questions related to the climate change problem. Issues such as the timing of optimal responses to climate change, the role of technological innovation and diffusion, the choice between domestic action and the adoption of "Kyoto mechanisms", the importance of co- and ancillary benefits, etc., have been analyzed from different perspectives. However, it is important to notice that the costs and benefits of all the above options crucially depend on the characteristics of the international agreement on climate change that is adopted. In particular, they depend upon two main features of the international regime: the number of signatories, and the size of their quantitative commitment to control GHG emissions.

It is therefore impossible to assess the costs and benefits of the Kyoto Protocol or of other potential agreements on climate change independently of the number of signatories of the agreement and of their abatement targets and/or policy commitment. However, the number of signatories is endogenous and depends on the abatement targets and mitigation polices adopted in various countries. Hence the weakness of most of the available literature on costs and benefits of climate change policies, which widely neglects the full interdependency between policies, costs–benefits, and signatories (more generally, the structure of the international agreements). For example, studies analyze the costs of implementing the Kyoto Protocol either through a set of domestic policies and measures or through a system of international tradable permits, with a fixed number of signatories. But the adoption of either policy crucially affects the number of signatories, which can be larger or lower under policies and measures than under tradable permits. And the number (and identity) of signatories crucially affects the costs and benefits of different agreements.

Therefore, this section aims to provide an analysis of the effectiveness of climate policies by focusing on the link between policy options on the one hand and the structure of the agreements and international regimes on the other. Some of the most important theoretical results are reviewed first, and then the existing literature is revisited to see which information it provides on the interdependencies described above. In particular, can such an analysis show whether there exist the conditions for an agreement on climate change to be signed by all or almost all world countries (see Carraro, 1998; Carraro and Siniscalco, 1998; and Barrett, 1999 for a theoretical analysis of these conditions)? Also, would it show which countries can play a leadership role with respect to achieving the largest possible coalition by proposing strategies, measures, and institutions that help expand the number of countries that commit to control their emissions (see Grubb and Gupta, 2000)? Notice that in this way we also analyze which strategies can be proposed to reduce the costs of mitigation policies. But this is a quite different approach to those analyzed in the previous sections of this chapter and in Chapters 8 and 9. The reason is that here a country's goal is not to identify a new climate friendly technology or an adequate redistribution of costs across sectors. Now the goal is to affect other countries' behaviour to increase the number of those that share the burden, and to share the burden more equitably.

The equity issue is also very important to understand which countries are going to reduce and/or control[5] their emissions.

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[5] When using the word "emission reduction", reduction with respect to the baseline scenario is meant here. As a consequence, emissions in some countries can increase with respect to their 1990 level or other baselines.

As a consequence, given what is said above, equity is crucial to assess adequately the costs of emission reductions at the global and country level. It has been argued that some countries are allowed to reduce emissions less than other countries, both within (Kram, 1998) and outside the European Union (EU) bubble (Bosello and Roson, 1999; Metz, 1999; Rose and Stevens, 1999). Even when applying the Kyoto mechanisms, some countries will benefit from the agreements more than other ones (Nordhaus and Boyer, 1999). It has also been argued that some countries can exploit their monopolistic power in a future trading system (Burniaux, 1998). All these remarks address the problem of optimal burden-sharing (the distribution of costs) of climate change control. This problem is strictly related to the features of an international agreement on climate for two main reasons. First, increasing the number of participating countries reduces the direct costs for each signatory; second, an agreement in which the burden is equitably shared is more likely to be signed by a large number of countries (Convery, 1999). Therefore, equity and the structure of the international agreement (number and identity of signatories) are strictly linked. However, the number of signatories affects and is affected by costs. Hence, equity and efficiency cannot be separated.

These remarks reinforce the previous basic statement. An analysis of the costs and benefits of different policy options, and of the distribution of these costs and benefits across countries, cannot be done independently of an analysis of the likely features of the prevailing international regime (i.e., of the incentives that lead countries to sign an international agreement to control GHG emissions and to set quantitative emission targets).

Notice that an analysis of the features of climate international agreements and of their repercussions on the choice of different policy options (and vice versa) must take into account:

- basic features of the climate problem recalled in Section 10.1, and particularly the public-good nature of GHG abatement in the absence of a supranational authority;
- scenarios that describe the future evolution of economic and environmental climate-related variables;
- economic incentives for countries to sign an international agreement on climate change control, that is under what conditions, in terms of the number of countries, damaging effects of free-riding (leakage), structure of costs and benefits, can a coalition (*i.e.*, a group of signatories of the international agreement) emerge?[6]
- the political and institutional dimension of an international climate agreement, its history, the possibility of monitoring and sanctioning deviations, the links with other agreements.

This section is devoted to the analysis of the above issues and also aims to provide a framework to understand how future negotiations on climate change can evolve, and how costs and benefits of climate policies are modified by these possible evolutions.

10.2.2 Coalition Formation

If the goal is to understand which international regime is likely to emerge to control GHG emissions, game theory is certainly the best tool. Indeed, game theory has been used extensively to analyze the possibility of coalition formation in the presence of free riding (i.e., when parties have to agree on the provision of a public good). Early contributions (see Hardin and Baden, 1977) characterized the environmental game among countries as a prisoners' dilemma, inevitably leading to the so-called "tragedy" of the common property goods. However, in the real world, at the same time, many international environmental agreements on the commons were signed, often involving subgroups of negotiating countries and sometimes involving economic and technological transfers and other links to other policies (trade, technological co-operation, etc.). It was therefore necessary to develop new models to help understand the logic of coalition formation in the presence of spillovers, and the possibility to increase welfare by means of appropriate mechanisms and strategies. These new models were developed in the 1990s within a non-co-operative game-theory framework, and provide interesting indications on the likely outcomes of climate negotiations.

Consider first the case in which countries negotiate on a single worldwide agreement. Most papers in the game-theory literature on coalition formation applied to environmental agreements (Hoel, 1991, 1992; Carraro and Siniscalco, 1992, 1993; Barrett, 1994, 1997b; Heal, 1994; Parson and Zeckhauser, 1995) propose the following conclusions:

- the presence of asymmetries[7] across countries and the incentive to free-ride makes the existence of global self-enforcing agreements, that is agreements which are profitable to all signatories and stable, quite unlikely (Carraro and Siniscalco, 1993);
- when self-enforcing international environmental agreements exist, they are signed by a limited number of countries (Hoel, 1991, 1994; Carraro and Siniscalco, 1992; Barrett, 1994); and
- when the number of signatories is large, the difference between the co-operative behaviour adopted by the coalition and the non-co-operative one is very small (Barrett, 1997b; Hammitt and Adams, 1996).

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[6] In the case of climate negotiations, possible coalitions are Annex B Parties of Kyoto Protocol, the Umbrella Group, UNFCCC Parties, *etc*.

[7] Herein countries are symmetric when they share the same production technologies, consumers' preferences, institutions, *etc.*, namely when their payoff (welfare) functions are identical.

The results are robust with respect to different specifications of countries' welfare function, and with respect to the burden-sharing rule[8] used in the asymmetric case (Barrett, 1997a; Botteon and Carraro, 1997a). They suggest that the attempt to negotiate effective emission reductions is unlikely to lead to a coalition formed by all or by almost all countries, unless more complex policy strategies, in which environmental policy interacts with other policy measures, are adopted.[9] This is why in the game-theoretic environmental economics literature two main sets of instruments are proposed to expand environmental coalitions, that is to increase the number of signatories of an environmental agreement. These instruments are "economic and technological transfers" and "issue linkage". The potential of these instruments is analyzed in Section 10.2.5, which deals with partial agreements and ways to broaden them.

Consider the case in which countries are free to sign the agreement proposed by a group of countries or to propose themselves a different agreement to the same or to other countries (Carraro, 1998). This may lead to the formation of multiple climate agreements, as happens with trade blocs (Bloch, 1997; Yi, 1997; Carraro and Moriconi, 1998). The multiplicity of coalitions may allow region-specific agreements in which the characteristics of countries in the region are better reflected by the contents of the agreement. Even in this case, game theory provides a clear analysis of the outcome of climate negotiations. Despite the large number of equilibrium concepts,[10] some conclusions seem to be quite robust:

- the equilibrium coalition structure is not formed by a single coalition, but usually by many coalitions;
- the grand coalition, in which all countries sign the same environmental agreement, is unlikely to be in equilibrium; and
- coalitions of different sizes may emerge at the equilibrium (even when countries are symmetric).

The specific results on the size of the coalitions depend on the model structure and, in particular, on the slope of countries' reaction functions (i.e., on the presence of carbon leakage). If there is no or little leakage and countries are symmetric, then the Nash equilibrium of the multicoalition game is characterized by many small coalitions, each one satisfying the properties of internal and external stability (this result is shown in Carraro and Moriconi, 1998).

The remaining question is therefore a policy one. Is a country's welfare larger when one or when several coalitions form? And what happens with environmental effectiveness? The answer is still uncertain, both because theory provides examples in which a single agreement is preferred, at least from an environmental viewpoint, to many small regional agreements (and vice versa), and because empirical studies have not yet convincingly addressed this issue. Moreover, the conclusion crucially depends on the choice of the equilibrium concept and on the size of leakage.

The consequence of the results discussed above is that the structure of the international environmental agreements is a crucial dimension of the negotiating process. If all countries negotiate on a single agreement, the incentives to sign are lower than those that characterize a multiple-agreement negotiating process. But at the equilibrium, the environmental benefit (quality) may be higher.

Can more precise conclusions be made on the likely coalition(s) that can emerge at the equilibrium? Can existing studies be used, albeit not in their design, to address the above issues, and to increase our understanding of the implications of different policy strategies? In the next section, the aim is to provide, at least partially, a synthesis, by exploring the outcomes of the combinations of different coalition structures (international regimes) and of different policy options (with focus on different degrees of adoption of emissions trading and other Kyoto mechanisms). *Table 10.2* summarizes the main combinations for which impact is explored. The papers indicated in each cell are examples and do not cover the literature in total.

10.2.3 No Participation

No participation constitutes the benchmark for evaluating the costs and benefits of policies designed to control GHG emissions under alternative coalition structures. It is usually named the baseline (or business as usual) scenario, because it identifies the values of the main environmental and economic variables when no coalition forms and no action, unilateral or co-operative, is adopted (IPCC SAR (IPCC, 1995) is a good example of this approach). The construction of the baseline scenario is very important to assess both the profitability and the stability (i.e., whether it is self-enforcing) of a coalition. A coalition is profitable when welfare after the coalition is formed is larger than in the no participation case. A coalition is self-enforcing if there are no incentives to leave or enter the

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[8] In the asymmetric case, the rule chosen to divide the gains from co-operation among the countries in the coalition (usually called burden-sharing rule) plays a crucial role because it affects the likelihood that each country decides to sign the agreement. The burden-sharing rule is usually taken from co-operative game theory and Nash's and Shapley's is the most used. In contrast, in the symmetric case different rules lead to the same outcome (equal shares).

[9] Surveys of the above literature are proposed in Barrett (1997b), Tulkens (1998), and Carraro (1999a).

[10] Unfortunately, game theory is far from achieving a well-defined non-co-operative theory of coalition formation under the above general assumptions and definitions. Several stability concepts can be used, but these unfortunately provide different equilibrium coalition structures. Among these are the concepts of equilibrium binding agreements (Ray and Vohra, 1997), α-stability and β-stability (Hart and Kurz, 1983), sequential stability (Bloch, 1997), open-membership stability (Yi, 1997), and far-sighted stability (Chew, 1994; Mariotti, 1997).

Table 10.2: *Coalition structures and policy options*

		Policy options						
		Domestic measures only	**Co-ordinated carbon tax**	**Flexibility mechanisms with ceilings**	**Free flexibility mechanisms**	**Flexibility mechanisms with banking**	**Flexibility mechanisms with R&D**	**Flexibility mechanisms with monopoly power**
Coalition structure	**No participation**	IPCC (1995)						
	Unilateral participation	Jorgensen *et al*. (1993) Barrett (1992)						
	EU only	Carraro and Siniscalco (1992)	Bosello and Carraro (1999) Barker (1999)					
	OECD only	Burniaux *et al*. (1992)	Capros (1998)		Harrison and Rutherford (1999) Holtsmark (1998) Capros (1998)			
	Annex-1 countries	McKibbin *et al*. (1998)	Mensbrugghe (1998) Buonnano	Ellerman *et al*. (1998) Holtsmark (1998) *et al*. (1999) Manne and Richels (1998)	Ellerman *et al*.(1998) Grubb and Vrolijk (1998) Westkog (1999) McKibbin *et al*. (1998) Manne and Richels (1999a, 1999b) Mensbrugghe (1998) Nordhaus and Boyer (1999) Shackleton (1998)	Bosello and Roson (1999) (1999)	Nordhaus (1997) Buonnano *et al*.	Burniaux (1998) Ellerman *et al*. (1998)
	Double umbrella				McKibbin *et al*. (1998) Shackleton (1998)			Ellerman *et al*. (1998)
	All countries	Nordhaus and Yang (1996)		Ellerman *et al*. (1998) Buonnano *et al*. (1999)	Bohm (1999) Ellerman *et al*. (1998) Manne and Richels (1998; 1999a, 1999b) Nordhaus and Boyer (1999) Shackleton (1998)	Bosello and Roson (1998) Westkog (1999)	Nordhaus (1997) Buonnano *et al*. (1999)	

coalition. The baseline scenario crucially affects these incentives also. If the no participation case is such that emissions decline and the target can be achieved easily through small emission reductions, then the incentives to join the coalition (sign the agreement) are much higher, so a coalition with many countries is more likely to form (Barrett, 1997b). Symmetrically, if large emission reductions are necessary, abatement becomes more costly, and incentives to free-ride increase, which further increases the costs for co-operating countries (particularly if leakage is high).

A careful definition of the no participation case is therefore very relevant to assess the likelihood of large coalitions and thus the efficiency of a climate agreement. But it is also very relevant in terms of equity. When the burden of emissions abatement has to be shared equitably, it is important to distribute emissions targets with reference to the baseline scenario. Each country therefore has an incentive to pretend that its own baseline scenario implies larger emissions than is actually true (Grubb, 1998; Bohm, 1999). In this way, the actual cost for the country would be lower. An optimistic scenario in which predicted emissions are lower than "true" emissions (as measured ex-post) leads countries to agree on low emission-reduction targets, but forces countries to more reductions later and to pay abatement costs larger than expected. A pessimistic scenario makes the agreement more difficult because larger emission reductions have to be agreed, but countries find themselves in a better situation and pay lower costs ex-post. Hence, if a country succeeds in convincing the others that its own baseline emissions are larger than the "true" ones, then this country achieves relative benefits in terms of less-stringent emission targets and lower abatement costs.

The definition of a baseline scenario has therefore a strategic dimension and can hardly be defined as an "objective" evaluation of future economic and environmental cycles and trends. It is therefore important to collect, as in Chapter 2, the largest amount of information from different sources and to identify the scenario more as an average of much scattered information, rather than as a subjective analysis of likely future events. This may reduce the likelihood of strategic definitions of the baseline scenario and may partly prevent the consequent impacts on the equilibrium coalition and on the assessment of costs and benefits of climate policies.

10.2.4 Unilateral Participation

An extensive literature analyses the costs and sometimes the benefits of introducing policies to control GHG emissions in a single country (Hoel, 1991; Bucholz and Konrad, 1994; Porter and Van Linde, 1995; Hoel and Schneider, 1997; Endres and Finus, 1998). Given the arguments proposed in the Introduction and the results summarized in Section 10.3.1, this type of exercise may seem unreasonable. There are, however, two main justifications for undertaking it. The first is that domestic abatement costs (related to domestic policies and measures) hardly depend on the coalition structure. Indeed, only if leakage is large, and if climate policies have a large impact on trade and financial flows, are the costs of domestic abatement policies significantly affected by the size of the coalitions and by the agreed emission targets. Hence, it may be useful to compute the costs of unilateral participation as a benchmark case, which identifies costs that can be reduced only when coalition forms and the Kyoto mechanisms are implemented among signatory countries. Notice the importance of a careful assessment of leakage and of trade and financial repercussions of climate policies (McKibbin *et al*., 1998). Notice also that the above arguments concern the costs but not the benefits of climate policies. Indeed, the climate benefits of unilateral participation are likely to be zero or almost zero for all or almost all countries (a possible exception is the USA), given the global nature of the climate problem (Hoel, 1991; Bucholz and Konrad, 1994; Endres and Finus, 1998).

A second reason to assess the cost of a unilateral participation is that it could identify a series of low cost (or no cost) options (so called low hanging fruits or no regrets actions) that could be implemented independently of the formation of a climate coalition. It could also help identify policy mixes that help restructure the fiscal system and public regulatory and incentive schemes in such a way that emission abatement costs are more than compensated by other economic (non-environmental) benefits (the so-called double dividends).[11]

There are also cases in which unilateral actions have been analyzed from a very specific viewpoint. Examples are:

- Bucholz and Konrad (1994) analyze the detrimental effect of pre-negotiation actions (more bargaining power can be achieved by unilaterally increasing emissions before negotiating);
- Endres and Finus (1998) examine the negative effects on negotiations of a higher environmental consciousness in one country;
- Hoel (1991) analyzes the costs of unilateral actions;
- Hoel and Schneider (1997) analyze the role of social norms; and
- Porter and Van Linde (1995) focus on the advantage of being a leader by adopting emission reductions before the other countries.

10.2.5 Partial Agreements

The case of partial agreements is most often analyzed in recent empirical literature, for two reasons. First, as shown in Section 10.2.1, theory suggests that a partial coalition forms at the equilibrium. Hence, the climate problem is neither a "tragedy of commons" nor a situation in which there are clear incentives to co-operative emission control. Second, the history of international environmental negotiations is a history of partial

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[11] See Chapters 7 and 8, and Goulder (1995), Bovenberg (1997), for surveys of this literature.

agreements that are slowly broadened as more and more countries decide to join the group of signatories. In the case of climate, in particular, the Kyoto agreement can be seen as a first partial climate agreement. Therefore, many papers have dealt with the costs and benefits of the Kyoto agreement and with the possible strategies to increase the number of countries that commit themselves to emission control targets (see the papers gathered in OECD (1998), and in Carraro (1999b, 2000); see also Burniaux (1998), Capros (1998), Ellerman *et al*. (1998), Grubb and Vrolijk (1998), Holtsmark (1998), Manne and Richels (1998), Mensbrugghe (1998), Carraro, 1999c), Nordhaus and Boyer (1999), and the surveys by Metz (1999) and Convery (1999)).

Two remarks are important. First, even if most recent analyses deal with the Kyoto agreement, there are studies that try to compute the optimal coalition structures, in terms of both participation and targets, independently of the decisions taken in Kyoto (a recent attempt is in Nordhaus and Boyer (1999)). Usually the conclusion derived from these papers is that Kyoto is neither economically nor environmentally optimal. However, the notion of optimality is not very useful when analyzing coalition formation. Indeed, what matters is the notion of the stability of a coalition. This identifies which countries have an incentive to join the coalition (sign the agreement) for different membership and institutional rules, baseline scenarios, abatement costs (and therefore climate policies, including the degree of adoption of Kyoto mechanisms), and environmental benefits (and therefore impacts, adaptation costs, etc.).

Second, the Kyoto agreement can theoretically be interpreted as a partial (Carraro, 1998) or as a global agreement (Chander *et al*., 1999). It is interpreted as a global agreement when all countries are seen as committed to emission targets. Those in Annex B are committed to emission targets with respect to 1990, the other ones are "committed" to emissions levels that evolve as in the baseline scenario. This second interpretation is nothing more than a "technical" interpretation, which is useful to show that:

- optimal emissions targets are not necessary because the same optimal outcome can be achieved through an international, unrestricted emissions-trading scheme among all countries (Chander *et al*., 1999); and
- the resultant outcome can be profitable to all countries if an appropriate economic and technological transfer scheme is adopted (Markusen 1975; Chander and Tulkens, 1995, 1997; Germain *et al*., 1997).

As a consequence, even a "partial", suboptimal agreement like Kyoto can be transformed into a "global" optimal agreement (see Section 10.3.5).

Away from this ideal world of perfectly competitive and international market mechanisms, are the analyses of coalitions that, like the coalition formed by Annex I countries of the UNFCCC or Annex B countries of the Kyoto Protocol, are partial (formed by a subgroup of the negotiating countries). In this context, four questions need to be answered:

(a) Are these partial coalitions effective?
(b) Are they too costly for the signatory countries?
(c) Can partial coalitions be enlarged by providing incentives for other countries to join? and
(d) Is there a distribution of emission targets and/or of abatement costs such as to increase the size of partial coalitions and hence the effectiveness of a climate agreement?

(a) The answer to the first question depends on two main factors: the baseline scenario and the degree of leakage. If the baseline scenario is very ambitious and leakage is high, then countries find it difficult to undertake large emissions reductions (decreasing returns of scale in emission abatement are usually assumed), and also their effort is offset by the leakage effect (the increased emissions by free-riding countries). Hence, a partial coalition is effective whenever there is no or little leakage, high pollution levels characterize the baseline scenario, and signatory countries contribute a large share of the total emissions.

(b) For the second question, many studies try to assess the cost for Annex I countries of achieving given emissions targets under alternative policy options. These policy options include:

- the timing of the mitigation responses (see the special issue of *Energy Economics* edited by Carraro and Hourcade (1999));
- the degree of adoption of the Kyoto mechanisms and their features, such as banking (see the papers in OECD (1998) and Carraro (1999d));
- the role of complementary industrial policies, mainly designed to foster innovation (see Nordhaus, 1997; Schneider and Goulder, 1997; Kopp *et al*., 1998; Buonnano *et al*., 1999); and
- the effects of uncertainty about climate impacts or abatement costs (Carraro and Hourcade, 1999).

The main result can be summarized as follows. Despite their high variability, all the studies show that the Kyoto mechanisms sensibly reduce the costs of compliance, whatever the coalition structure. Hence, emissions trading, and more generally the application of the Kyoto mechanisms, can reduce overall mitigation costs without reducing the effectiveness of the climate policy. Chapters 6 and 8 give an extensive overview of relevant studies.[12]

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[12] For example, Shogren (1999) notes that "it is estimated that any agreement without the cost flexibility provided by trading will at least double the USA costs, … the key is to distribute emissions internationally so as to minimise the costs of climate policy". Manne and Richels (1999b) state that losses in 2010 are two and one-half times higher with the constraint on the purchase of carbon emission rights; international co-operation through trade is essential if we are to reduce mitigation costs (see also Glomstrod *et al.*, 1992; Burniaux, 1998; Capros, 1998; Ellerman *et al.*, 1998; Mensbrugghe, 1998; Hourcade *et al.*, 1999; Nordhaus, 1999; Rose and Stevens, 1999; Tol, 1999a, 1999b).

If assuming an even broader type of flexibility than incorporated in the Kyoto mechanisms (banking and borrowing and international emissions trading (IET) among all countries) then compliance costs are further lowered. This result is shown in Bosello and Roson (1999) for banking, Westskog (1999) for banking and borrowing, Manne and Richels (1999a, 1999b), McKibbin *et al*. (1998), and many others for IET among all countries. If in addition the incentives to innovation provided by the Kyoto mechanisms are taken into account, then compliance costs are even lower (Buonnano *et al*. 1999).

However, all the above papers also show that the size of the coalition crucially affects the size of the benefits that derive from the adoption of the Kyoto mechanisms. The larger the number of participating countries, and the higher the variability of marginal abatement costs across them, the larger the benefits from emissions trading and the clean development mechanism (CDM). Hence, to reduce abatement costs and increase environmental benefits, policies, rules, and institutions should be designed to achieve the largest possible coalition.

(c) The third question, how to broaden a climate coalition, is often related to the issue of links between a climate agreement and other international agreements. Indeed, two types of policy options, based respectively on economic and technological transfers and on issue linkage, are often proposed as the way to achieve larger climate coalitions. These policies imply that links must be established between different multilateral agreements (e.g., agreements on both climate and free trade or technological co-operation).

First, consider economic and technological transfers. It is quite natural to propose these transfers to compensate those countries that may lose by signing the environmental agreement. In other words, a redistribution mechanism among signatories, from gainers to losers, may provide the basic requirement for a self-enforcing agreement to exist, that is the profitability of the agreement for all signatories. Therefore, if well designed, economic and technological transfers can guarantee that no country refuses to sign the agreement because it is not profitable. Moreover, Chander and Tulkens (1995, 1997) and Chander *et al*. (1999) show economic and technological transfers exist such that not only is each country better off within a global coalition than it is with no coalition at all (the no participation case), but also it is better off within a global coalition than it is in any subcoalition, provided the remaining countries behave non-co-operatively (see also Markusen 1975; Germain *et al*., 1997). This result is important because it implies that no country or group of countries has an incentive to exclude other countries from the environmental coalition, that is the grand coalition is optimal (but it may not be stable).

Economic and technological transfers play a major role also with respect to the stability issue (Carraro and Siniscalco, 1993; Petrakis and Xepapadeas, 1996; Schmidt, 1997). Indeed, it is not sufficient to guarantee the profitability of the environmental agreement. Incentives to free-ride also need to be offset. The possibility of using self-financed economic and technological transfers to stabilize environmental agreements is analysed in Carraro and Siniscalco (1993) and Hoel (1994), which show that these transfers may be successful only if associated with a certain degree of commitment. For example, when countries are fairly symmetric, only if a group of countries is committed to co-operation can another group of uncommitted countries be induced to sign the agreement by a system of economic and technological transfers (Carraro and Siniscalco, 1993).[13] This gives developed countries the responsibility to lead the expansion of the coalition. However, the amount of resources that would be necessary to induce large developing countries to join the agreement may be such that some developed countries perceive the economic costs of a climate agreement to be larger than its environmental benefit. In this case, the transfer mechanism would undermine the existence of the leader coalition and would therefore be ineffective. This is why countries in the leader coalition must be strongly committed to co-operation on emission control.

Another general conclusion emerges from the analysis carried out in Carraro and Siniscalco (1993): both the existence of stable coalitions and the possibilities of expanding them depend on the pattern of interdependence among countries. If there is leakage (i.e., a non-co-operating country expands its emissions when the coalition restricts them, thus offsetting the effort of the co-operating countries), then environmental benefits from co-operation are low, the incentive to free-ride is high, and conditions for economic and technological transfers to be effective are unlikely to be met. If, on the contrary, there is no leakage (i.e., the free-riders simply enjoy the cleaner environment without paying for it, but do not offset the emission reduction by the co-operating countries), then environmental benefits are larger, free-riding is less profitable, and transfers may achieve their goal to expand the coalition.

A second policy strategy aimed at expanding the number of signatories to a climate agreement is based on the idea of designing a negotiation mechanism in which countries do not bargain only on GHG reductions, but also on another interrelated (economic) issue. For example, Barrett (1995, 1997c) and Kirchgässner and Mohr (1996) propose to link climate negotiations to negotiations on trade liberalization, Carraro and Siniscalco (1995, 1997) and Katsoulacos (1997) propose to link them to negotiations on R&D co-operation, and Mohr (1995) proposes a link to international debt.

Again we must distinguish the profitability from the stability problem. The idea of "issue linkage" was originally proposed by Folmer *et al.* (1993) and Cesar and De Zeeuw (1996) to solve the problem of asymmetries among countries. The intuition is that some countries gain on a given issue, whereas other countries gain on a second one. By "linking" the two issues it

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[13] This condition is less stringent when countries are asymmetric (see Botteon and Carraro, 1997a).

may be possible that the agreement in which the countries decide to co-operate on both issues is profitable to all of them. The idea of "issue linkage" can also be used to achieve the stability goal. If countries that do not sign a climate agreement do not enjoy the benefits that arise from signing simultaneously other multilateral agreements (e.g., those on technological co-operation), then incentive for all countries to sign the linked agreement is strong.

This approach is likely to function when the negotiation on an issue with excludable benefits (a "club good" in economic words) is linked to the climate negotiation (which, if successful, typically provides a public good, that is a non-excludable benefit). An example could be the linkage of environmental negotiations with negotiations on technological co-operation whose benefits are largely shared among the signatories whenever innovation spillovers to non-signatories are low (see Carraro and Siniscalco, 1997).[14]

Therefore, issue linkage may be a powerful tool to address the enlargement issue. If the developed countries (USA, EU, and Japan above all) increase their financial and technological support to developing countries, and also make this support conditional on the achievement of given environmental targets, then other countries are likely to be induced to join the environmental coalition (i.e., to sign a treaty in which they commit themselves to adequate emission reductions).[15]

(d) The final question concerns the link between equity[16] and the size of a climate agreement and, as a consequence, between equity and the agreement's environmental effectiveness. It has been shown that the use of different criteria to share the cost of a given emission target crucially affects the size of the equilibrium coalitions, that is the number and identity of signatory countries (Barrett, 1997a; Botteon and Carraro, 1997a, 1997b; Eyckmans, 2000). For the Kyoto Protocol, Convery (1999) argues that without assigning generous emission targets to Russia and Ukraine, these countries would not have signed the agreement. Eyckmans (2000) proves the same conclusion by simulating different equilibrium climate coalitions with the Regional Integrated Model of Climate and the Economy (RICE). Indeed, without implementing the Kyoto mechanisms, Russia and Ukraine have an incentive not to ratify the protocol, whereas with joint implementation (JI) and trading, and with the possibility of exchanging excess GHG emissions, all countries find it profitable to ratify the protocol. Bosello *et al.* (2000), using again the RICE model, confirm the same results and analyze different distributional rules in terms of their impacts on the equilibrium climate coalitions. They show that the Kyoto Protocol could be sustained and possibly expanded by adopting a more equitable sharing of the emission reduction commitments.

10.2.6 Global Agreements

The difficulty of achieving a global agreement on climate change underlined in the previous sections depends on four main factors:

- *The heterogeneity of countries with respect to the causes of climate change, the impacts, and the mitigation and adaptation costs*. This factor mainly influences the profitability of the decision to sign a climate agreement. Some countries may lose when signing the agreement, even when environmental benefits are fully accounted for. As shown by Chander and Tulkens (1995, 1997), there always exists a system of economic and technological transfers that may make all countries gain. But this again raises the equity problem and the related burden-sharing issue. Equity may have a large impact on the existence and size of a climate coalition. As previously argued, and as argued by many policymakers and scientists, the way in which the burden of controlling emissions is shared across countries crucially affects a country's decision to join a coalition. On the one hand, if the burden is not equitably shared, some countries may not find it profitable to sign the agreement. Profitability depends on two main factors: (1) the distribution of costs within the coalition and (2) the size of the coalition. It is possible that there exists a minimum size of the coalition above which it becomes profitable. And these two factors are strictly interdependent. On the other hand, equity also affects free-riding incentives. As in Section 10.2.5, in some cases it may be reasonable for some countries to transfer resources to other countries to induce them to join the coalition on which they would otherwise free-ride. In this case, the final outcome is not equitable–free-riders would gain more than countries in the starting coalition–but it may be environmentally and economically efficient.
- *The strong incentives to free-ride on the global agreement and the lack of related sanctions.* When all countries agree to control emissions, a defecting country achieves the whole benefit, because its incidence on global emission is marginal (with a few exceptions) and pays no cost. Hence, a defection with respect to a large coalition is the optimal strategy if there are no sanctions. However, credible sanctions are difficult to design (Barrett, 1994). Emissions themselves are hardly a credible sanction, because countries are unlikely to sustain self-damaging policies. Moreover, in this case,

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[14] An extension to the case of structurally asymmetric countries is provided in Botteon and Carraro (1997b), whereas information asymmetries are accounted for in Katsoulacos (1997).

[15] It is, however, important to keep in mind the negative impact that such linkages may have on the (perceived) fairness of the envisaged enlarged regime: there are possible linkages that could easily be perceived as "blackmail" on part of the Parties with strategic advantages.

[16] For equity principles see Chapter 1, Section 1.3

asymmetries play a double role: some countries may not gain from signing the environmental agreement, whereas some countries, even when gaining from environmental co-operation, may lose from carrying out the economic sanctions (Barrett, 1997c; Schmidt, 1997).

- *The absence of environmental leadership.* The process of achieving a global agreement can be a sequential one (Carraro and Siniscalco, 1993), in which case a group of countries take the leadership, start to reduce and/or control emissions and implement strategies such as to induce other countries to follow.[17] The presence of low-cost climate policies and equitable burden-sharing (Schmidt, 1997) are again important elements for the formation of an initial profitable coalition. As said, our definition of profitability accounts for the environmental benefits of emission control. Hence, benefits should be increased by increasing the number of countries that control emissions, but abatement costs should be minimized by exploiting all possible opportunities (including emissions trading). This is a prerequisite to achieving a strong leader coalition that can exert its leadership through the design of better negotiation rules, the implementation of transfer mechanisms, and the credibility of international-issue linkages. A preliminary model of the effects of leadership is given in Jacoby *et al*. (1998), who show how and when developing countries may join a leader coalition formed by Annex I countries.
- *The focus on a single international climate agreement*. As explained in Section 10.3.1, if countries may join different coalitions, which means that several agreements can be signed by groups of countries in the same way as countries form trade blocs, then the likelihood that all or almost all countries set emission reduction targets increases (Yi and Shin, 1994; Bloch, 1997; Carraro, 1997, 1998). The outcome of negotiations in which more agreements can be signed is usually a situation with several small environmental blocs (Carraro and Moriconi, 1998), but this can be considered a step in the right direction. If all or almost all countries set emission reduction targets within their own bloc (e.g., regional environmental agreements are signed), then, in a subsequent phase, negotiations among blocs may lead to more ambitious emission reductions.

Despite the warning that global agreements may be difficult to reach, many articles analyze the costs of agreements in which all countries participate, in one form or another (see, e.g., Capros, 1998, Ellerman *et al*., 1998; Manne and Richels, 1998; Shackleton, 1998; Bosello and Roson, 1999; Nordhaus and Boyer, 1999). The weakest form, discussed in Section 10.2.4, is that in which a few countries commit to emission reductions, but all accept trade emissions in a single international market. The strongest form is that in which a central planner is assumed to set optimal emissions levels for all world countries. This optimal solution is often proposed as a benchmark for actual negotiations and was often analyzed before Kyoto (see the collection of papers in Carraro (1999d)).

More interesting is the attempt made by Peck and Teisberg (1999) to model the negotiations between developed and developing countries to achieve a global agreement. This paper shows the potential for the achievement of co-operation to be achieved–the Pareto frontier is small, but not empty–but does not analyse the incentives to actually sign the agreement. However, the paper suggests a research direction that at least helps to identify the optimal emission reductions that are profitable for all negotiating countries.

The conclusions that can be derived from this type of empirical analyses are similar to those already mentioned for partial agreements. In the scenario in which baseline emissions are lower, it is easier to achieve a global agreement because lower emissions reductions are necessary (Barrett, 1997b) and consequently abatement costs are lower. Optimal emissions targets are such that they equalize marginal abatement costs. This optimal, cost-minimizing solution can also be achieved through an unconstrained emissions-trading system (Chander *et al*., 1999). Hence, either emissions targets are optimally set, or countries are allowed to trade emissions for any given set of targets through which a global consensus can be achieved. Of course, these two options have different impacts on equity. As shown by Bosello and Roson (1999), starting from the Kyoto targets, international unconstrained emissions trading among all countries achieves optimality, but reduces equity.

10.2.7 Political Science Perspectives

Game theory and other rational-choice approaches are used frequently in political science. However, political science research considers political processes in more detail and their findings complement the results presented above, at least on three major issues. Although these extensions have important implications for the conclusions here, the basic insights remain the same.

While game theory analysis usually models states as *unitary* actors, much political science research conceives of states as complex political systems. The behaviour of a complex actor can be seen as a function of three main determinants: the internal configuration of preferences, the internal distribution of influence and power, and the nature of political institutions (which specify the decision rules). Domestic decision-making processes often produce outcomes that differ significantly from those that maximize the net national welfare. Particularly relevant in this context are three findings that illustrate systematic biases.

First, in "baseline" circumstances, the measures that are most easily adopted and implemented are those that offer tangible

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[17] See Carraro (1999b) and Grubb (1999) for a more detailed analysis.

benefits to a specific sector of the economy or organized segments of society, while costs are widely dispersed throughout society (Underdal, 1998). For most conventional environmental-protection measures, costs are concentrated while benefits are indeterminate or widely dispersed, which indicates that—unless the issue really mobilizes the general public—the odds favour opponents to the measures, particularly in the implementation phase.

Second, (environmental) damage that hits the "social centre" of society tends to generate more political energy than damage that affects the social periphery only. This bias is stronger the more skewed the distribution of economic and political resources. This suggests, for example, that damage suffered primarily by poor farming communities in developing countries generates a less vigorous political response than damage that hits the infrastructure of the "modern" sectors of the economy (e.g., as a consequence of extreme weather events).

Third, domestic political processes often generate political "friction" that limits the scope for international package deals and compensatory arrangements. Only compensation that benefits the domestic actor(s) who are blocking a particular solution–or more powerful actors–will be fully effective. Only a subset of the compensatory arrangements that make sense in terms of economic criteria will pass the test of political feasibility. These issues of national DMFs are explored in Section 10.1.

Most of the research reviewed above examines climate change policy in isolation, on its own merits only. In the real world, new issues enter a policy space that is already crowded by other problems competing for attention. In such an environment, the priority given to a particular issue and the chances that a particular option will be adopted depend on how well it combines with other salient concerns. As we have seen in, for example, the acid rain case, policy confluence and synergy can make a significant difference for some of the parties. However, although the causal mechanism itself is well understood, it is triggered by circumstances that occur more or less at random. Thus, the aggregate net impact in terms of the climate change regime cannot be predicted (even if issue linkage, as seen above, may be a powerful strategy).

The conventional assumption in game theory analysis is that each party aims to maximize its own welfare, defined—when dealing with environmental problems—in terms of damage and abatement costs. Political science research modifies this assumption in three different directions.

First, it introduces a distinction between the "basic game" itself (i.e., the system of activities to be regulated) and the "policy game" through which decisions about regulations are made. The policy game generates its own stakes; certain kinds of behaviour—notably behaviour that meets the expectations of domestic "clients" and important others—are rewarded, while moves that violate these expectations are punished. Governments also consider such political stakes. Where such stakes exist, a political scientist expects government behaviour to deviate to some degree from what national economic interests indicate. Such deviance may go both ways; the wish to placate politically important domestic "clients" most often leads to a more restrictive policy, while the momentum generated towards the end of a successful international conference can lead a lone "laggard" to go the extra mile to accommodate the majority.

Second, political science emphasizes (more and more) the relevance of "social norms", "social learning", and the operation of "social roles" in regime processes (Young, 1999). These approaches recognize that all international environmental regimes are "social institutions" that develop particular (social) dynamics and induce behavioural consequences: the matter of *social norms* refers to behaviour that roots in considerations of legitimacy or authoritativeness. Actors, who regard the rules of regimes as legitimate, often comply without engaging in detailed calculations of the costs and benefits (of their doing so). One important effect of international regimes is that they initiate *social learning processes*. Already, the start of global negotiating generally has resulted in the generation of new facts, ideas, and perspectives that reduce uncertainty and lead to changes in the prevailing discourses, values, and actual behaviour of actors. The operation of *social roles* refers to the observation that actors regularly take on new roles under the terms of institutional arrangements that shape identities and interests.

Third, norms of fairness are assumed to serve as (1) frameworks of soft constraints upon the pursuit of self-interest, and (2) as decision premises in situations in which interests provide no clear guidance. Studying international negotiations we can observe some rather general norms that are frequently invoked and very rarely disputed—at least on principled grounds. These norms seem to constitute a soft core of widely, though probably not universally, accepted ideas about distributive fairness. This core is described in summary fashion below.

The default option in international co-operation is the norm that all parties shall have *equal* obligations, usually defined in relative terms. The principle of equal obligations has a firm normative basis if all parties involved are roughly equal in all relevant respects. This condition is never met in global negotiations, although it usually applies to subgroups. When the range of variance exceeds a certain threshold, attention shifts to some notion of *equity*. The common denominator for equity norms is that costs and/or benefits be distributed in (rough) proportion to actor scores on the dimension(s) that led the parties to think about differentiation in the first place. Several such dimensions can be identified, but in international co-operation attention focuses primarily on two. One is the role that each party played in causing the problem or providing the good in question, the other refers to the consequences that a particular obligation or project would have for the various parties involved. This gives a matrix with four key principles (see *Table 10.3*). In a global setting, however, the range of variance in terms of criteria such as "guilt" or "capacity" is most often so large that even the

Table 10.3: *Key principles of equity in the political science context*

Focus on ↓	Object to be distributed	
	Costs (obligations)	**Benefits**
Cause of current state of affairs	"Guilt" or responsibility (for causing the problem)	Contribution (to solving the problem or providing the good)
Consequences for actors	Capacity (ability to pay)	Need

notion of soft proportionality leads to "unfair" burdens upon the poorest countries. When the latter threshold is reached, attention tends to shift to the simple principle of *exemption*; more precisely, exemption from any substantive obligation for which a party is not (fully) compensated.

This leaves a somewhat complex and elastic framework, but the bottom line is clear enough. A global agreement has to be at least roughly consistent with (1) the general pattern of differentiation outlined in the preceding paragraph, and (2) the combined implications of the equity principles of "guilt", "capacity", and "need" (i.e., implications that can be derived from all three principles).

These points are important to consider in the design of international environmental regimes. Political scientists focus on sociopolitical dimensions and processes that current game-theory models neglect or are unable to capture adequately. Nevertheless, the policy-relevant conclusions from game theory remain valid and useful for the policy process.

10.2.8 Implementation and Compliance

Since SAR, political science analysis in the field of effectiveness and implementation of international environmental agreements has focused on the process of implementation. That is, how intent is translated into action to solve international environmental problems and what are the real effects of these efforts (Sand, 1992; Haas *et al.*, 1993; Young, 1994, 1999; Brown Weiss and Jacobson, 1998; Victor *et al.*, 1998). Analysts distinguish "implementation" and "compliance"

Box 10.1. Definitions of Political Science Terms

Implementation

Implementation refers to the actions (legislation or regulations, judicial decrees, or other actions) that governments take to translate international accords into domestic law and policy (Jacobson and Brown Weiss, 1995; Underdal, 1998; Brown Weiss, 1999). It includes those events and activities that occur after authoritative public policy directives have been issued, such as the effort to administer the substantive impacts on people and events (Mazmanian and Sabatier, 1983). It is important to distinguish between the legal implementation of international commitments (in national law) and the effective implementation (measures that induce changes in the behaviour of target groups; see Zürn, 1996).

Compliance

Compliance is a matter of whether and to what extent countries do adhere to the provisions of the accord (Jacobson and Brown Weiss, 1995; Underdal, 1998). The concept of compliance includes implementation, but it is generally broader. Compliance focuses not only on whether implementing measures are in effect, but also on whether there is compliance with the implementing actions. Compliance measures the degree to which the actors whose behaviour is targetted by the agreement (whether they be local government units, corporations, organizations, or individuals) conform to the implementing measures and obligations (Brown Weiss, 1999).

Effectiveness

Effectiveness measures the degree to which international environmental accords lead to changes of behaviour that help to solve environmental problems, that is the extent to which the commitment has actually influenced behaviour in a way that advances the goals that inspired the commitment (Victor *et al.*, 1998).

Enforcement

Enforcement refers to the actions taken once violations occur. It is customarily associated with the availability of formal dispute settlement procedures and with penalties, sanctions, or other coercive measures to induce compliance with obligations. Enforcement is part of the compliance process (Brown Weiss, 1999).

(Chayes and Chayes, 1993, 1995; Mitchel, 1994; Jacobson and Brown Weiss, 1995; Cameron *et al*., 1996; Underdal, 1998; Victor *et al*., 1998; Brown Weiss, 1999). See *Box 10.1*. for the definition of political science terms.

Although compliance is an important matter for the outcome of an agreement, it has to be distinguished from the effectiveness of the accord (Underdal, 1998; Victor *et al*., 1998; Brown Weiss, 1999; Young, 1999). This refers to the extent to which the commitment actually influences behaviour in a way that advances the goals that inspired the commitment.

Discussions are underway on how to enforce international commitments, that is to make parties to the international treaties conform with their international obligations through application of various tools (penalties, sanctions, *etc*.). Some researchers argue that enforcement might be especially difficult in international systems and, thus, is often unlikely unless a party persistently fails to comply.[18] Besides, non-compliance is frequently the product of incomplete planning and miscalculation rather than a wilful act (Victor *et al*., 1998). Thus, enforcement is often contrasted to the management of non-compliance and implementation failures (non-compliance is a problem to be solved, not an action to be punished), which includes greater transparency, non-adversarial forms of dispute resolution, technical and economic assistance, persuasion, and negotiation (Haas *et al*., 1993; Chayes and Chayes, 1995; Sand, 1995; Downs *et al*., 1996; Zürn, 1996; Peterson, 1997; Victor *et al*., 1998; Vogel and Kessler, 1998). However, there are also good reasons to consider coercive “enforcement” techniques–in cases of severe violations they may be more effective. In this debate, standard solutions do not exist and a mixed approach seems to be reasonable.

The challenge today is how decisions regarding compliance and implementation of the UNFCCC and its Kyoto Protocol should be undertaken to make these international mechanisms more effective in solving the problems of both combatting global climate change and changes in the behaviour of the targets (Victor and Salt, 1995; O’Riordan and Jäger, 1996; O’Riordan, 1997; Soroos, 1997; Grubb *et al*., 1999). Two crucial aspects of decision-making regarding implementation of the international climate change regime are:

- how national governments have translated international commitments into national rules and policies, and promote changes in behaviour of stakeholders; and
- how international institutions have aided monitoring of implementation and compliance, adherence to commitments, and adjustment of international rules by the parties.

Inadequate attention to implementation at both national and international levels is largely the reason why many international agreements have fallen short of their promise (Victor *et al*., 1998). Moreover, as the policy agenda has grown more demanding, international agreements play an ever greater role in affecting and co-ordinating the behaviour of national governments that have undertaken the international obligations and became responsible for meeting them. These agreements also influence the activities and responses of non-state actors (such as firms, individuals, scientists, interest groups, consumer and environmental groups), whose activities are affected by the international treaties after national governments adopt rules and policies for domestic implementation of the international regime. The importance of implementation has increased, and climate change is a good example of this. The stakeholders come to play an increasing role in design and implementation of the treaties (Michaelowa, 1998b; Victor *et al*., 1998; De La Vega Navarro, 2000), and to involve them more broadly makes this process more effective.

Success or failure in the implementation of international environmental agreements depends to a large extent on how they are implemented in countries, once the parties to the agreements have returned back home. The process of domestic implementation of international environmental arrangements is very important to the overall effectiveness of the treaty. Results of attempts to develop co-operative solutions to international environmental problems are found in the domestic setting of the decision-making (Hanf and Underdahl, 1995; Hanf and Underdal, 2000). Indeed, to understand what is likely to happen at the international level, it is necessary to examine the underlying factors and processes, structures, and values at the national level (Kawashima, 1997; Kotov *et al*., 1997; Kawashima, 2000). These determine the manner in which national positions on negotiating international agreements are arrived at and the ultimate agreements are then carried out. In turn, the expectation is that what has happened or is happening in various international arenas influences these domestic processes and decisions within individual countries; thus, national–international linkages within the decision-making process are very strong.

The decision-making and policy-making processes pertaining to international co-operation in the environmental field may be represented as a sequence of three interrelated phases (Hanf and Underdal, 1995):

- formation of national preferences and policy positions for international negotiation;
- translation of national preferences into international collective action; and
- implementation of international agreements at the national level.

The first two phases are analyzed from both economic and political science perspectives. As for the third phase, studies demonstrate that there are no standard decisions or standard implementation processes for the international environmental regimes. Even countries with similar political, economic, and social systems adopt different approaches, and within countries

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[18] This is why in Sections 10.2.2–10.2.6 the focus is on self-enforcing agreements.

the implementation process varies markedly among different sectors. It is expected that implementation of the climate change international regime will illustrate this conclusion, and the canvas for the decision-making process will be extremely intricate and complex.

The literature on compliance and implementation indicates that a variance in the extent to which parties to international agreements fulfil their obligations, and that the extent of national compliance also varies across international regimes (Jacobson and Brown Weiss, 1995; Downs *et al*., 1996; Brown Weiss, 1999; Young, 1999).

Signing (and ratification) of an international agreement constitutes no guarantee that it will be implemented effectively and complied with. Nor does the refusal to sign an agreement necessarily mean that an actor will act contrary to its terms. Moreover, an actor may comply with some provisions (e.g., procedural obligations), but not with others (e.g., substantive rules that require major behavioural change), and meet some obligations partially (for example, by reducing emissions, but less and/or later than required by the agreement). It is necessary to note that rule-consistent behaviour may not always be induced by the treaty, or necessarily result from the existence of a particular agreement. For one thing, some international agreements do not require that all actors change their behaviour—some actors may already behave as prescribed by regime rules (Brown Weiss and Jacobson, 1998). Moreover, in some cases for which behavioural change is prescribed, the required change may come about without any deliberate effort to meet the obligation, and compliance without implementation occurs. For example, the recent sharp economic recession in Russia (more than a 50% decrease in Gross National Product (GNP) during the 1990s) resulted in sufficient pollutant-emission reduction from industrial and other activities to meet (and even to "over-comply with") the domestic targets set by a number of international agreements. Little effort was required on the part of the government or non-government actors to honour these commitments (Kotov and Nikitina, 1996, 1998). A number of recent research efforts conclude that most domestic behavioural change can be attributed to many exogenous factors, and is not induced directly by the international regime, but this change contributes to compliance with the regime goals and targets (Levy *et al*., 1995). These specifics affect seriously decision-making patterns regarding the implementation of the climate change regime.

Recent research brings together several important paths that can influence the variance in the extent to which parties fulfil their obligations (Haas *et al*., 1993; O'Riordan and Jäger, 1996; Zürn, 1996; Peterson, 1997; Victor *et al*., 1998). Enhancement of a contractual environment refers to the high relevance of an institution's transparency and credibility. An effective design introduces a shared set of norms and rules, provides information about membership and compliance, and helps to reduce transaction costs. Concern building describes the potential influence of institutions on actors' beliefs and ideas. These actors create, collect, and disseminate scientific knowledge and serve as centres for social learning processes. Capacity building refers to asymmetries across countries and their restrictive effects on an international commitment and to the possibilities of overcoming them. International institutions can manage transfers of cognitive, administrative, and material capacities to enable states to agree and comply with obligations. A broadly accepted management of non-compliance in many cases can lead to more effective solutions to defection. This approach of flexible responses covers various instruments, such as dispute resolution, interacting measures of assistance and persuasion, incentives, and greater transparency. Participation by "target groups" (e.g., regulated industries) and other non-governmental organizations (NGOs) reduces uncertainty, leads to more realistic agreements, and helps to ensure that countries put them into practice.

10.2.9 Monitoring, Reporting, and Verification

Studies confirm that in the past compliance of nearly all governments with their binding international environmental obligations has been quite high. However, this often reflects that the commitments were fairly trivial, in many cases simply codifying rather than changing behaviour (Brown Weiss, 1999; Victor and Skolnikoff, 1999). But the effectiveness of these commitments in reducing environmental problems was also low. Incentives to cheat were few and the need for strict monitoring and enforcement was low. As efforts to tackle environmental problems intensified, as in the case of climate change, countries' commitments became more demanding and stringent, the costs and complexity of implementation increased, and thus the incentives to cheat have grown. For this reason, stricter monitoring and enforcement are increasingly essential to ensure that these commitments are implemented fully (Sand, 1996; Victor and Skolnikoff, 1999). The historical record of high compliance without much monitoring and enforcement is a poor indicator of what will be needed for more effective international environmental protection in the future.

Although systematic reviews of implementation are commonplace in many national regulatory programmes (Lykke, 1993), the systematic monitoring, assessment, and handling of implementation failures by international institutions is relatively rare (General Accounting Office, 1992). Nonetheless, efforts to provide such review are growing, and today formal mechanisms for implementation review exist in nearly every recent international environmental agreement. Such mechanisms are incorporated into the UNFCCC structure as well (Victor and Salt, 1995). In addition, many informal mechanisms to review implementation and handle cases of non-compliance often operate in tandem with the formal mechanisms. Together, these formal and informal mechanisms are termed by some researchers as "systems for implementation review".

An implementation review process is especially vital when decisions are undertaken regarding complex and uncertain problems on the international environmental agenda. Such problems as global warming are still poorly understood, and involve a large number of stakeholders. Since regulation of the many diffused actors is often complex, governments cannot be sure in advance whether their efforts to put international commitments into practice will be successful. Moreover, some governments may intentionally violate their international obligations. Thus, there is a need to review implementation and handle problems that arise. Implementation review can also make it easier to identify problems with existing agreements, which can aid the process of renegotiation and adjustment. However, until recently implementation review has neither been the topic of much research nor high on the policy agenda.

International agreements that include procedures for gathering and reviewing information on implementation and handling implementation problems, as for the UNFCCC, are more likely to be effective than those in which little effort is given to developing the functions of implementation review (Zürn, 1996; Victor *et al*., 1998). Agreements contain prescriptions for the governments to report regularly the data on their emissions and implementation measures. This has made parties more accountable for the implementation of their commitments, helped to direct assistance that facilitates compliance, and provided information and assessments that make it easier to adjust agreements over time.

Within the decision-making process regarding UNFCCC implementation, today more attention is given to assessing national emissions, policy, and measures. The process of compiling GHG emission inventories is well underway. Parties to the UNFCCC are obliged to compile and submit national communications on how they are implementing the convention (Green, 1995). These reports include inventories of GHG emissions, reports on policies and measures that the parties have adopted to try to stabilize or reduce emissions, and (eventually) an account of the extent to which emission abatement has been successful. Since 1991, IPCC and the Organization for Economic Co-operation and Development (OECD) have built effective guidelines for inventory reporting. All parties to the convention must use this system of reporting to the UNFCCC regarding emissions by sources and removals by sinks. Within this framework the governments are actively contributing to the international reporting process in submitting their national reports. Experts regard data reported by them as the backbone of the IPCC international system, while the EU is also engaging its own system – Coordination-Information-Air (CORINAIR). Without good data, systems of implementation review work poorly or not at all (Lanchbery, 1998). This system was intended to be applicable to all countries and for the main emissions sector (that for energy-related CO_2 emissions), and it makes use of energy flow statistics of the type that most developed countries collect routinely. Special methodologies and guidelines have been elaborated to convert the national inventory systems reasonably well, certainly for energy-related emissions, into the IPCC format. In this and in other respects it is what is known largely as a “top down“ system.

Nevertheless, much work needs to be done and decisions undertaken in this area soon. Assessments indicate the poor quality of data. National data of the member states for major GHGs are not comparable, accurate, or reliable outside the energy sector (Lanchbery, 1997): emission figures given in national inventories are often of poor quality (in many subsectors, no estimates are made at all by some countries). This is not surprising given the rapid development of the climate issue and the requirement for reliable inventories. However, it impedes significantly the simplest reviews of implementation.

At the moment the reporting process may not be transparent enough. Further decisions could be undertaken, both at national and international levels, to improve its effectiveness. That is, to improve and develop further the compilation methodologies, increase the transparency of the compilation process and its reliability, and more work is needed that is specifically directed towards obtaining information for inventories, rather than purely for scientific purposes. It is crucial that inventories of GHGs are accurate, reliable, and comprehensive. Otherwise, it is not possible to determine the state of the emissions, where they originate, and how they are changing.

As the climate change regime develops after Kyoto, the issues of emissions measurement and verification, including the release and absorption of carbon from changes in land use, rice cultivation, and forest management, will become even more important. And it represents one of the toughest challenges for the scientific community. By adding three additional gases and sinks, the Kyoto Protocol fulfils its ambition to be more complete, but at the same time it makes compliance more difficult, and it complicates monitoring and verification (Corfee-Morlot and Schwengels, 1994). In particular, it raises the need for further modelling, a comprehensive new analysis, and better inventories.

Targets agreed by Kyoto are challenging. However, to implement the commitments and to meet the targets it is necessary to reach a common understanding of what they mean. Forecasts from different sources are often not comparable. For example, data from the International Energy Agency (IEA) are different from national figures. Even different ministries in the same country, let alone in other countries, use different assumptions, which significantly hampers the comparability of data. Assumptions on burden sharing and cost-effectiveness analysis become more difficult or even arbitrary. Thus, one of the first decisions regarding the steps of Kyoto Protocol implementation should be to make the data and assumptions to be used more consistent.

Verification and monitoring mechanisms are of particular importance to implement flexible mechanisms. Without a clear definition, measurement, and inventory of emissions and emissions reduction, binding targets cannot be achieved and flexible mechanisms cannot be realized, as is stressed in various parts of the Kyoto Protocol. Baseline calculations, monitoring, and verification play a crucial role in measuring emissions reductions that result from JI and CDM projects, and thereby ensure that these projects are based on real environment improvements (Jepma and Munasinghe, 1998). Decisions and agreement among parties is urgently needed on firm rules based on accepted methodologies (e.g., benchmarking). The same applies to emissions trading: rules that govern emissions-trading markets must be simple and transparent. Particularly important are rules on the total number of permits available in the market, the permit tenure (their duration), eligibility criteria, the method of initial permit allocation, and the monitoring mechanism.

How to make the verification and enforcement system more effective? Several suggestions in this respect refer to environmental agreements in general (Green, 1993). Different coercive measures, such as trade sanctions and other penalties, may be needed in cases of severe violations. To date, practice shows that sanctions have been used rarely, but when applied they have often been effective (Victor, 1995). A looming challenge is to determine when and how sanctions can be made compatible with international trade rules. Potential conflicts between the sanctions that have sometimes been vital to international environmental co-operation and the free-trade rules that discourage sanctions have not been tested or settled. There are also suggestions to use, for reluctant countries, various compensations for the costs of implementing the treaties (compensation for national reporting testifies to this approach). Other suggestions include bilateral funding programmes. Several funding programmes have been undertaken to support the compilation and reporting of national inventories by the developing countries and countries with economies in transition.

Regimes that elicit the most co-operation have at their disposal more powerful carrots and sticks with which to enforce international obligations. Such tools are increasingly being used, and they work—especially when the sanction is to withdraw financial assistance. The threat of cutting off finance has brought swift compliance. The combination of soft management backed by strict enforcement when necessary has been effective. The most flagrant violations have been deterred and reversed only when strong incentives, including threats of trade sanctions, have been applied (Chayes and Chayes, 1995).

Such market-based mechanisms as GHG emissions trading also may be regarded as a tool to make the UNFCCC implementation easier and less costly for many developed countries. The Kyoto Protocol envisions creating a system of internationally tradable emissions rights that can be used to lower the cost of cutting emissions of GHGs. The international use of market-based incentives is virgin territory. There are no direct historical precedents, and there is much to be learned about the institutions that will be needed to enable the successful international use of market-based systems.

10.3 Local and/or National Sustainable Development Choices and Addressing Climate Change

10.3.1 Introduction

Chapter 1 presented three perspectives on climate change mitigation: cost-effectiveness, equity, and sustainability. The first perspective dominates much of the assessments reviewed in the previous chapters and sections. It is also dominant in the scientific literature on climate change mitigation. As discussed in Sections 1.3 and 1.4, other key perspectives are relevant for mitigation assessment as well: equity and sustainability. This is especially relevant for the assessment of mitigative capacity at local and national levels, and certainly for incorporating climate change mitigation policies into national development agendas.

Decision making related to climate change is a crucial aspect of making decisions about sustainable development, simply because climate change is one of the most important symptoms of “unsustainability”. Climate change could undermine economic activities, social welfare, and equity in an unprecedented manner, in particular both intra- and intergenerational equity is likely to be worsened. Now it is widely recognized that global environmental problems and the ability to meet human needs are linked through a set of physical, chemical, and biological processes that have an impact on global hydrological cycles, affect the boundaries and functioning of ecological systems, and accelerate land degradation and desertification.

Despite the close links, climate change and sustainable development have been pursued as largely separate discourses. The sustainable development research community has not generally considered how the impacts of changing climate may affect efforts to develop more sustainable societies. Conversely, methodological and substantive arguments associated with sustainable development are still absent in climate change discourse. It is difficult to generalize about sustainable development policies and choices. Sustainable development implies and requires diversity, flexibility, and innovation. Policy choices are meant to introduce changes in technological patterns of natural resource use, production and consumption, structural changes in the production systems, spatial distribution of population and economic activities, and behavioural patterns. Moreover, the process of integrating and internalising climate change and sustainable development policies into national development agendas requires new problem-solving strategies and decision-making approaches in which uncertainties need to be managed to produce robust choices.

In this section the dual structure of linkages between sustainable development and climate change is discussed. The existence of positive synergistic effects is reviewed, as is how specific strategies, especially those related to lifestyle options and technology-transfer policies, could reinforce potential synergies. Finally, the emergence of new and innovative decision frameworks, in which extended peer community participation is essential to incorporate into the decision process both the plurality of different legitimate perspectives and the management of irreducible uncertainties in knowledge and ethics, is examined.

10.3.2 Development Choices and the Potential for Synergy

Chapter 1 provides a concise overview of sustainable development as a context for climate change mitigation policy. As argued there, the concept of sustainable development defies objective interpretation or operational implementation. However, it is precisely the diversity of interpretations that "makes up the biggest advantage of the concept: it is sufficiently rich and flexible to refract the full diversity of human interests, values and aspirations" (Raskin *et al.*, 1998). So nearly everyone can agree that sustainable development is a good thing, and consensus has become possible over broad policy areas in which previously people could not agree. Or, in the words of O'Riordan (1993), "sustainable development may be a chimera. It may mark all kinds of contradictions. It may be ambiguously interpreted by all manners of people for all manners of reasons. But as an ideal it is nowadays as persistent a political concept as are democracy, justice and liberty."

Now, sustainability is perceived as an irreducible, holistic concept in which economic, social, and environmental issues are interdependent dimensions that must be approached in a unified framework. However, the interpretation and valuation of these dimensions give rise to a diversity of approaches. Different disciplines have their own conceptual framework, which translates into different variables, different pathways, and different normative judgements. Economists stress the goal to maximize the net welfare of economic activities, while maintaining or increasing the stock of economic, ecological, and sociocultural assets over time. The social approach tends to highlight questions of inequality and poverty reduction, and environmentalists the questions of natural resource management and ecosystems' resilience (Rotmans, 1997). Apart from the weight placed on each of the critical dimensions, the important conclusion from this ongoing debate is that achieving sustainable economic development, conserving environmental resources, and alleviating poverty and economic injustice are compatible and mutually reinforcing goals in many circumstances.

While the overall literature on sustainable development is very large, the literature that focuses on concrete policies to make operational the concept of sustainable development is, however, much smaller. This asymmetric coverage of the guidance and the operational principles for managing a sustainable development path constitutes a non-negligible barrier to an effective decision-making process, since policymakers lack concise and relevant information that would allow them to assess alternative development choices.

10.3.2.1 Decision-making Process Related to Sustainable Development

Actions that steer the course of society and its economic and governmental organizations are largely tasks of making decisions and solving problems. This requires choosing issues that require attention, setting goals, finding or designing suitable courses of action, and evaluating and choosing among alternative actions. The first three of these activities—fixing agendas, setting goals, and designing actions—are usually called problem solving; the last, evaluating and choosing, is usually called decision making (Simon *et al.*, 1986). Except for trivial cases, decision making generally involves complicated processes of setting actions and dynamic factors that begins with the identification of a stimulus for action and ends with a specific commitment to action (Mintzberg, 1994). The complexity of the decision-making process related to sustainable development becomes even more problematic simply because the difference between the present state and a desired state is not clearly perceived, so "we have a better understanding on what is unsustainable rather than what is sustainable" (Fricker, 1998).

Much of the ambiguity arises from the lack of measurements that could provide policymakers with essential information on the alternative choices at stake, on how these choices affect clear and recognizable social, economic, and environmental critical issues. Such measurements could also provide a basis for evaluating policymakers' performance in achieving goals and targets. Management requires measurement and now, as never before, government institutions and the international community are concerned with establishing the means to assess and report on progress towards sustainable development. "If we genuinely embrace sustainable development, we must have some idea if the path we are going on is heading towards it or away from it. There is no way we can know that unless we know what it is we are trying to achieve—i.e. what sustainable development means—and unless we have indicators that tell us whether we are on or off a sustainable development path" (Pearce, 1998). Therefore, indicators are indispensable to make the concept of sustainable development operational. They are particularly useful for decision making because they help (Hardi and Barg, 1997):

- understand what sustainable development means in operational terms (in this sense, measurement and indicators are explanatory tools, which translate the concepts of sustainable development into practical terms);
- make policy choices to move towards sustainable development (measurement indicators create linkages between everyday activities, and sustainability indicators provide a sense of direction for decision makers when they choose among policy alternatives, that is they are planning tools); and
- decide how successful efforts to meet sustainable development goals and objectives have been (in this sense measurement and indicators are performance assessment tools).

The past few years have witnessed a rapidly increasing interest in the construction of sustainable development indicators to assess the significance of sustainability concerns in economic analysis and policy. Different analytical frameworks have been suggested to identify, develop, and communicate indicators of sustainability. Hardi and Barg (1997), in an extensive survey of ongoing work on measuring sustainability, discuss the advantages and limitations of different approaches from the viewpoint of their practical applicability. The main differences among frameworks are (1) the ways and means by which they identify measurable dimensions, and select and group the issues to be measured; and (2) the concepts by which they justify the identification and selection procedure. Some of the major frameworks are briefly summarized below.

One of the most prominent is the Human Development Index developed by the United Nations Development Programme (UNDP) to ranks a country's performance on the criteria of human development, instead of solely the economic performance. Though the index was not developed as a sustainable development index, recent efforts have been made to supplement it with an environmental dimension to encompass explicitly the multiple dimensions of sustainability. Integrated environmental–economic accounting is a framework that is rapidly gaining prominence. The basic idea of this approach is to establish links between the conventional circular production–consumption economic accounting to the natural support system through the extraction of resources in one direction and the discharge of residuals in the other (Tietenberg, 1996). Another framework that is attracting a high level of interest is the multiple capital approach. This approach recognizes that a country's wealth is the combination of economic, environmental, and social capital and these dimensions of capitals should be preserved, enriched, or substituted if consumed. The World Bank's *Measure of the Wealth of Nations* (World Bank, 1997) is the most notable application of this framework. The concept of genuine savings is introduced in the World Bank approach to measure the true rate of saving of a nation after accounting for the depreciation of produced assets, the depletion of natural resources, investments in human capital, and the value of global damages from carbon emissions. Lastly, the Pressure–State–Response framework (OECD,1993; UNCSD, 1996) focuses on the causal relationships between stress-generating human activities, changes in the state of the natural and social environment, and society responses to these changes through environmental, general economic, and sectoral policies.

Different sets of thematic indicators are devised for use at different scales. The broadest scale is the international or global level. In this context, global conventions and protocols, such as the climate, biodiversity, desertification, and ozone agreements, are extremely important. It is becoming increasingly clear that unless specifically tailored indicators are developed and monitored, the implementation of these conventions is not possible. Both the secretariats of the conventions and international agencies are working intensely not only to identify and develop appropriate indicators, but also, most importantly, to give them acceptability in the eyes of the international community (Gallopin, 1997).

At the national level, several important steps to make operational the concept of sustainable development have being undertaken. Different sets of thematic indicators are being used for each of the major issues in national environmental policy, reflecting differences in national endowment, level of development, and cultural traditions, as well as the heterogeneity within countries. The indicators generally cover every aspect of pollution control, nature conservation, resource depletion, social welfare, health, education, employment, waste management, etc.—in short, a compendium of all the components of traditional development goals and conventional policy debate. Hence, factors that distinguish sustainable development from traditional development tend to be submerged under a sea of age-old problems that are made no more readily soluble by bearing the name sustainable development (George, 1999). The point is that current definitions of indicators and the use of terminology are particularly confusing and some clarity and consensus is required about the definition of what an indicator is, as well as in the definition of related concepts such as threshold, index, target, and standard. This consensus cannot be based solely on political agreement; logical and epistemological soundness is also necessary (Gallopin, 1997).

It is recognized (Hardi and Barg, 1997) that much work remains to be done. Some approaches lack causal linkages or they tend to over simplify interlinkages and relations among issues; others focus on the measurement of those segments of sustainable development that can be expressed in monetary terms; in some cases detailed calculations of indicators are highly technical and difficult to handle. Fresh initiatives oriented to capture complex interlinkages in the interactions between human activity and the environment, especially those related to pressure–state–response causalities, have been undertaken in recent years (Meadows, 1998; Bossel, 1999). Undoubtedly, all these efforts are needed to provide decision makers with information and operational criteria to assess current situations and evaluate strategic decisions. Furthermore, these efforts hold the additional promise of treating environmental problems within a framework that the key institutions and agencies in any government will understand.

10.3.2.2 Technological and Policy Options and Choices

It is clear from the preceding discussion that governments' commitments to sustainable development require indicators by which decision makers can evaluate their performance in achieving specific goals and targets. Furthermore, such indicators are essential, first to capture the complex interlinkages between the basic building blocks of sustainable development (environment, economic activity, and the social fabric), and second to balance the unavoidable trade-offs between the main policy issues related to each of these blocks (development, equity, and sustainability).

It is difficult to generalize about sustainable development policies and choices. Sustainability implies and requires diversity, flexibility, and innovation. Thus, there cannot be one "rightful" path of sustainable development that leads finally to a blissful state of sustainability (Bossel, 1998). Depending upon differences among individual countries (size, level of industrialization, cultural values, etc.) as well as on the heterogeneity within countries, policy choices are meant to introduce changes in:

- *Technological patterns of natural resource use, production of goods and services, and final consumption*. These encompass individual technological options and choices as well as overall technological systems. Sustainable development on a global scale requires radical technological changes focused on the efficient use of materials and energy for the sufficient coverage of needs, and with minimum impact on the environment, society, and future. This is of particular importance in developing countries, in which a major part of the infrastructure needed can avoid past practices and move more rapidly towards technologies that use resources in a more sustainable way, recycle more wastes and products, and handle residual wastes in a more acceptable manner. As discussed in Chapter 3, the range of opportunities is extensive enough to cope with different development styles and national circumstances, but what is even more important, economic potential increases as result of the continuous process of technological change and innovation. A number of technologies that less than 10 years ago were at the laboratory-prototype stage are now available in the markets. Issues on barriers and opportunities for technology development, transfer, and diffusion at the national level are discussed in Chapter 5 and Section 10.3.3 below.
- *Structural changes in the production system*. Economic growth continues to be a widely pursued objective of most governments and, therefore, policy decisions on development patterns may have direct impacts on both raw material and the energy content of production. Structural changes towards services or a low energy-intensity industrial base may or may not affect the overall level of economic activity, but could have significant impacts on the energy content of goods and services.
- *Spatial distribution patterns of population and economic activities*. Country-wide policies on the geographical distribution of human settlements and productive activities impact on sustainable development at three levels: on the evolution of land uses, on mobility needs and transport requirements, and on the energy requirements. These factors are of utmost relevance for most developing countries, in which spatial distributions of the population and of economic activities are not yet settled. Therefore, these countries are in a position to adopt urban and/or regional planning and industrial policies directed towards a more balanced use of their geographical space.
- *Behavioural patterns that determine the evolution of lifestyles*. Consumption behaviours, and individual choices in general, have a critical influence on sustainable development. After all, sustainability is a global project that requires big and small daily contributions from almost everybody (Bossel, 1998). Personal opportunities and freedom of choices are embedded in cultures and habits, but these are also shaped and supported by the products and services provided by the economic system, as well as by the organization and administration at all levels. Within the boundaries of individual freedom, government policies can discourage unsound consumption styles and encourage more sustainable social behaviour through the adoption of financial incentives (subsidies), disincentives (taxes), legal constraints, and the provision of wider choices of infrastructure and services. This point is elaborated further in Section 10.3.2.3.

The set of specific policies, measures, and instruments to mitigate climate change and consequently promote sustainable development is quite large. These include generic policies oriented to induce changes in the behaviour of economic agents, or control and regulatory measures to achieve specific targets at the sectoral level. A comprehensive discussion of various aspects of different types of policies and measures is presented in Chapter 6. Here it is important to note, first, that sustainability issues cannot be addressed by single isolated measures, but they require a whole set of integrated and mutually reinforced policies. Second, weights assigned to different policies depend on individual countries according to their national circumstances and specific priorities. Third, the cause–effect reaction in the process of policy implementation is not linear. Except in trivial cases, policies tend to disrupt existing patterns, social systems create and respond to changes within themselves through feedback loops, and new patterns emerge as social, economic, and environmental aspects interact in the process of convergence towards the desired goals.

10.3.2.3 Choices and Decisions Related to Lifestyles

There are two reasons why lifestyles are an issue of climate policy. First, consumption patterns are an important factor in climate change since they have become an essential element of lifestyles in developed countries. If, for instance, people changed their preferences from cars to bicycles, this would alleviate climate change and decrease mitigation costs considerably. Second, many promising domains for substantial environmental improvements through technological change also require changes in lifestyle. With respect to traffic, for instance, to reach sustainability beyond that of increases in efficiency requires changes in the modal split and ultimately in urban planning (Deutscher Bundestag, 1994). Yet lifestyles have been subjected to far less systematic investigation than technology (Duchin, 1998, p. 51). In SAR they were not discussed at all.

The concept of lifestyle (*Lebensführung*) was introduced by Weber (1922). Lifestyle denotes a set of basic attitudes, values, and patterns of behaviour that are common to a social group, including patterns of consumption or anticonsumption. It seemed for a while that a change from environmentally less benign to more benign consumption patterns had emerged by itself (Inglehart, 1971, 1977) in the 1970s. What really happened, however, was not a switch from one coherent and dominant set of values to another, but an end of coherence through a pluralization of values (Mitchell, 1983; Reusswig, 1994; Douglas *et al*., 1998). Current lifestyles reflect this patchwork of values. Some of these, however, are environmentally more benign than others. The idea of promoting transfers from the latter to the former must take into account that lifestyles are not just a matter of behaving this or that way, but are basically an expression of people's self-esteem (see below). Lifestyles, therefore, are based on ideas with respect to the individual's identity. To this extent the issue is not only that individuals need to change their behaviour, but that they need to change themselves. This tends to be underestimated in policy considerations, but must be accounted for when such changes become relevant with respect to climate change. Otherwise discrepancies between people's environmental consciousness and behaviour are deplored but not understood.

10.3.2.3.1 Lifestyles as an Expression of Identity

As far as an individual's behaviour can be explained in terms of economic rationality, changes in lifestyles would seem to be a matter of changing relative prices of commodities by economic policy. In general, however, the rationality of human behaviour is beyond economic rationality. Examples from India as well as from the USA are referred to by Douglas *et al*. (1998), who note that the majority of lifestyles are "not economically rational, but they are still culturally rational". Therefore "the social and cultural dimensions of human needs and wants must be included in the theoretical approaches."

In cultural anthropology human behaviour is interpreted in terms of finding one's place within the social universe by relating oneself to others (not only to the proverbial Joneses next door), that is by setting up distinctions in the community. In doing so commodities are a means of discrimination. They "constitute the visible part of culture as the tip of the iceberg which is the whole of the social processes" (Røpke, 1999). Of course, many goods satisfy needs as well, but they do even this because of their social capacity to make sense in the individual's social context. This explanation of human consumption behaviour—as advanced by Douglas and Isherwood (1979)—seems to be considerably more comprehensive than a purely economic one. However, even if in their account "human beings are conceived of as social, ... they are just as unpleasant pursuers of their own interests as they are in economics" (Røpke, 1999).

Goods, however, make sense not only with respect to others. It has been observed in marketing research that people since the 1960s have gradually passed from buying goods like food, clothing, or housing to basically buying personality, the hardware commodities being part of that (Tomlinson, 1990). In doing so an individual relates to him- or herself rather than to others. Consumers by now are "engaged in an ongoing enterprise of self-creation, ... a 'cultural project' ... the purpose of which is to complete the self" by consumption (McCracken, 1988, p. 88). As far as consumption is responsible for climate change, this means that people in developed countries (and their fellow consumers in less-developed countries) aim for self-realization at the expense of others.

The general rule is that human behaviour expresses one's implicit or explicit self-definition (Meyer-Abich, 1997). Moisander (in press) points out that this project of identity is not limited to the paradigm of the rational, autonomous, and self-certain individual. In the consumer society "The ways in which people relate to their possessions can be seen as reflections of how they view themselves and relate to their social and physical environment" (Dittmar, 1992, p. 125). They express who we are, even if they do so not necessarily in a consistent way. The "social life of things" (Appadurai, 1986) animates all kinds of commodities.

All this seems to imply that any attempt to change lifestyles intentionally is bound to fail. Intercultural experience, however, shows that "the Western conception of the person as a bounded, unique, more or less integrated motivational and cognitive universe ... is ... a rather peculiar idea within the context of the world's cultures" (Geertz, 1979, p. 229). Although in the Western world even the modern state is supposed to have been established by an agreement of independent, or decontextualized individuals, the question "Who am I?" in other cultures is generally answered by reference to the contexts in which one belongs. That is, to dependencies, and not by independence claims with respect to oneself. Western people tend to believe that they are what they are just for themselves, as if everybody had only his or her first name, but even in Europe the idea of individual salvation after death, for instance, did not develop before the 12th century (Ariès, 1977). In contrast, intercultural studies have shown that traditional Asian, African, Latin American, and even Southern European concepts of self indicate an interdependent identity (Cousins 1989; Markus and Kitayama, 1991). This means "that behaviour is seen as context-bound and aimed towards a harmonious fit with the expectations and evaluations of others, who are continuously involved in one's definition of self" (Dittmar, 1992, p. 190). The barrier of consumption-based identity at the expense of others might, therefore, be overcome by contextualizing the Western self in intercultural communication. Section 10.3.2.3.2. gives some indications of how this could be fostered politically.

10.3.2.3.2 Policies and Options for Change

Environmental education

Although political attention is always in a process of change, public awareness of environmental disruption in general and climate change in particular is at a fairly high level in many developed countries, and has been rising over a long period. This consciousness is generally ahead of the corresponding behaviour, yet (apart from governmental action):

- in many countries citizens initiatives offer bottom-up solutions for alternative consumption patterns (Georg, 1999); and
- environmental behaviour tends to cover consciousness in low-cost situations, that is if the costs and inconvenience are not much higher for the environmentally more benign solution (see Diekmann and Preisendörfer (1992) for Germany and Switzerland).

Interestingly enough, these low-cost limits appear mainly to be a matter of equity—not to pay too much more than one's fellow citizens—because environmental legislation (for everybody) is accepted beyond those limits. Politically, environmental consciousness can be promoted by environmental education. This includes primary schools as well as high schools, adult education, and particularly lecturer's education at the college and university level. Environmental education could be more effective than it has proved so far if it recognized that human behaviour hinges on lifestyle or self-awareness.

Decreasing marginal satisfaction with rising private material consumption

John Stuart Mill's idea that in affluent societies people might prefer other forms of satisfaction to ever-increasing consumption of purchased commodities is not prominent in contemporary economics, but has not completely disappeared from economic thought (see Harrod, 1958; Hirsch, 1977; Xenos, 1989). Now there are indications that the marginal utility of those commodities is steadily decreasing with rising consumption (see Scherhorn, 1994; Inglehart, 1996). For instance, although consumption in the USA has doubled since 1957, it is reported that the average US citizen considers his or her happiness to have decreased since then (UNDP, 1998). Sanne (1998) reports from Sweden that 87% of the people have a car, but 14% of these do not "need" it while only 47% consider it to be "necessary". Similarly, 52% have a dishwasher, but 30% of these do not "need" it and only 12% deem it "necessary". The mismatch between economic consumption and the satisfaction of human needs is shown by the Index of Sustainable Economic Welfare. This ran parallel to GNP up to the 1970s, but rapidly departed after that (Nordhaus and Tobin, 1972; Daly and Cobb, 1989; Jackson and Marks, 1999). If these discrepancies became a political issue the personal relevance of consumption patterns could decrease. Politically, the introduction of a suitable index of welfare and stimulation of public dialogue on the goals of economic action could foster this.

New emphasis on immaterial and common goods

Goods may be either common or private and either material or immaterial, so four combinations arise:

- private material goods (e.g., house or car);
- private immaterial goods (e.g., well-being or creativity);
- common material goods (e.g., shared cars or household appliances); and
- common immaterial goods (e.g., environmental quality or collective actions, such as the liberation of a creek, common attendance of public facilities, etc.).

Among the four combinations, so far economic analysis of consumption has been based mainly on only one, private material goods. Since marginal satisfaction with these is decreasing, the neglected combinations have been reconsidered recently (Scherhorn, 1997). This is particularly relevant with respect to climate change, because immaterial and common goods (irrespective of their material basis) are or stimulate social activities that promote the integrity of society. They either foster the natural environment or endanger it much less than private and material goods generally do in terms of production, consumption, and waste management. Material goods are not an end in themselves, so that their real utility is different from their material reality. Politically, public education in consumer's behaviour can promote the awareness that identities can be expressed by a broader plurality of goods than just material and private goods.

New deals in collective action

Climate is a common public good and the debate as to what extent "commons" can be appreciated in market-based economies is ongoing. Much of the discussion originally derives from Olson's (1965) argument that if people were rational egoists in the sense of liberal economics, individual rationality must lead to collective irrationality in large informal groups, because free riders could not be excluded. As non-irrational collective actions exist, human behaviour cannot only be motivated by rational egoism, the problem posed by Olson's analysis was to identify these other motivations. Udéhn (1993) summarized the subsequent discussion comprehensively. The main outcome confirms that human co-operation generally cannot be explained economically, but only by taking into account social or personal commitments. Sen (1976/77, 1985) noted that such commitments can replace economic "rationality", or utility maximization. He also argued, that commitments are related to a person's "identity" (discussed above as the key to lifestyles). These identities, however, are not fixed once and for all but develop through social intercourse. Correspondingly, one of the most consistent results of the debate on collective action is that "co-operation increases dramatically if people are allowed to communicate before being subjected to a social dilemma" (Udéhn, 1993; see Dawes, 1980; Orbell *et al.*, 1984; van de Kragt *et al.*, 1986). This may be expected in market behaviour as well, so that environmental commitments can overcome price incentives. By co-operation in the common interest there is also "reason to believe that appeals to the full set of motivations and behaviours—accompanied by an analysis of bold options—can encourage lifestyle decisions that reduce pressures on the environment" (Duchin, in press).

Environmental legislation

Democratic governments cannot go far beyond public consciousness in environmental legislation. To the extent that people deliberately pay higher prices for environmentally more benign goods, as has been discussed above, governments can increase this threshold step by step.

Creative democracy

Better understanding (as the Olson debate has shown) can lead to the perception of common interests, but such understanding does not necessarily come about by itself. Its promotion is rather an objective of "creative democracy" (Burns and Ueberhorst, 1988). Generally, this is again a matter of education, particularly of political education. "Education and productive employment ... would be worth while policy goals in relation to global climate change" (Douglas *et al*., 1998). Education implies formal and informal processes of creativity as well as receptivity, so that not only schools and universities are to be addressed here. For instance, in Germany most cities have their special Agenda 21 program, supported by citizens' movements and by an Agenda 21 office in local government. This stimulates learning by doing. The administration is in charge here not simply to implement sustainability locally, but to promote understanding as well as co-operation in the global interest of sustainability. A broad public dialogue can also encourage public confidence in making changes for the advantage of nature, the developing countries, and future generations. For behavioural change, "arguably the most important obstacle is the difficulty of imagining new scripts and removing the obstacles to actually living them" (Duchin, in press). If that public dialogue, therefore, is mainly concerned with such "new scripts", even the discrepancy between environmental consciousness and behaviour might finally disappear, so that people as consumers would no longer lag behind themselves as citizens.

Research needs

Lifestyle research is neglected compared to technology research, even where technological and lifestyle changes are linked. Particularly, nature-saving lifestyles and the general process of self- and world-constitution through goods are enormously understudied (see McCracken, 1988).

10.3.2.4 Interaction of Climate Policy with other Objectives

The linkages between the social, economic, environmental, and political dimensions of sustainable development call for policies that can serve multiple objectives, and requires that a balance be struck when objectives conflict. These linkages are often mutually reinforcing in the long run, but may sometimes be contradictory in the short term (OECD, 1999c). In this regard, a critical requirement of sustainable development is a capacity to design policy measures that, without hindering development and remaining consistent with national strategies, could exploit potential synergies between national economic growth objectives and environmentally focused policies. Climate change mitigation strategies offer a clear example of how co-ordinated and harmonized policies can take advantage of the synergies between the implementation of mitigation options and broader objectives.

Over the past years, of the policy options to mitigate climate change, technological options to limit or reduce GHG emissions have received by far the most attention. Chapters 3 and 4 provide a comprehensive review of technologies and practices to mitigate climate change. Energy efficiency improvements (including energy conservation), switches to low carbon-content fuels, use of renewable energy sources, and the introduction of more advanced non-conventional energy technologies are expected to have significant impacts on curbing actual GHG emission tendencies. Similarly, the adoption of new technologies and practices in agriculture and forestry activities, as well as the adoption of clean production processes, could make substantial contributions to the GHG mitigation effort. Depending on the specific context in which they are applied, these options may entail ancillary benefits, and in some cases are worth undertaking whether or not there are climate-related reasons for doing so.

The potential linkages between climate change mitigation issues and economic and social aspects have also brought an important shift in the focus of mitigation analysis literature. From being confined to project-by-project or sector-based approaches, analyses and studies are increasingly concerned with broader policy issues as mechanisms to reduce the increase of GHG emissions. Fresh methodological developments (UNEP, 1998) broaden climate change mitigation policies by incorporating distributional impacts, negative side effects, and the appropriate choice of instruments and institutional constraints, among others. This provides a somewhat different slant on the focus of climate change mitigation policies. More emphasis is now given to exploit mutually reinforcing links among individual actions, to take advantage of the potential interactions of mitigation options with other objectives, and to supplement individual mechanisms with economic instruments of wider scope.

10.3.2.5 Synergies, Trade-offs, and No Regrets

The existence of ancillary benefits and synergies in implementing mitigation options has been addressed in a preliminary way in IPCC (1996c). These issues are discussed in detail in Chapters 7, 8 and 9. Some relevant findings are highlighted here. The adoption of more sustainable agricultural practices in Africa (Sokona *et al*., 1999) illustrates clearly the mutually reinforcing effects of climate change mitigation, environmental protection, and economic benefits. In fact, the introduction or expansion of agroforestry and organic agriculture (i.e., methods that intensify agricultural production while using less input), can improve food security and at the same time reduce GHG emissions. In agroforestry systems, trees are planted to delineate plots of land, and further to fix nitrogen, causing the nutrients lower in the soil to rise up. The trees also prevent soil erosion, supply firewood and animal fodder, and constitute a source of income. Organic farming improves the fertility of the soil through the addition of organic matter. The damage and diseases caused by insects are virtually eliminated through the technique of "growing in corridors" and other holistic methods. Costly inputs are not used at all or are kept to a minimum, and the system is flexible. In addition, these methods restore and maintain carbon levels in the soil. Hence, if practised on a large scale, they could transform soils from carbon sources into carbon sinks.

Energy efficiency improvements and energy conservation are other issues of economic and strategic concern. In developing countries, energy demand (for electricity in particular) continues to grow at a rate that is often hard to keep up with. The adoption of environmentally sound technologies (ESTs) for both energy production and energy consumption would enable these countries to lower the pressure on energy investments, reduce public investments (in some cases by up to one-third (World Bank, 1994)), improve export competitiveness, enlarge energy reserves, and also avoid a large increase in GHG emissions. Thus the alternative energy paths of low-carbon futures in developing countries can be compatible with national objectives. Such paths could prevent energy and/or GDP intensities from following the growth path of the developed world, in which energy demand and GDP elasticity first increased with successive stages of industrialization, but since have sharply decreased.

A large number of similar synergy effects can be found in industry, transportation, and human settlement patterns. For example, more decentralized development patterns based on a stronger role for small- and medium-sized cities can decrease the rural exodus, reduce needs for transportation, and allow the use of modern technologies (biotechnology, solar energy, wind, and small-scale hydropower) to tap the large reserves of natural resources. Building upon the lending experiences of World Bank operations and sector programmes in a number of countries, Warford *et al*. (1996) provide evidence for the positive linkages between economic policies and the environment. Although environmental concerns, and climate change issues in particular, were not explicitly addressed by macroeconomic and sectoral policies, the country cases analyzed show clear synergies between reform policies and environmental improvements. In some cases when adverse side effects do occur, the remedy is not to reverse the reform policies, but rather to introduce specific complementary measures that address the negative effects.

Finally, it is important to underline that for the elements that constitute policies at different levels to operate in a mutually reinforcing manner, the creation of appropriate communication and information channels should be given special attention. The topic of establishing effective and stable flows of communication among different stakeholders is seldom addressed in connection with climate change mitigation. This is mainly because policies related to climate change tend to treat mitigation options as isolated projects, each falling into a narrow area in which potential synergies may be ignored or misunderstood. As result, environmental policies risk resulting poorly structured interventions, with a limited scope of influence, and an overestimated cost-effectiveness (Eskeland and Xie, 1998). Greater synergies could be achieved if agencies with global and local agendas did business together, through effective linkage mechanisms that allow co-ordination and support in implementing tasks or functions that belong to different subsystems and involve different actors.

10.3.2.6 Links to other Conventions

Awareness of the complex system of interrelated cause-and-effect chains among climate, biodiversity, desertification, water, and forestry has been growing in recent years. Now it is widely recognized that global environmental problems and the ability to meet human needs are linked through a set of physical, chemical, and biological processes. Climate change, for example, alters the global hydrological cycle, affects the boundaries and functioning of ecological systems, and accelerates land degradation and desertification (*Figure 10.5*). These negative impacts in turn reinforce each other through feedback loops, which results in a serious threat to land productivity, food supply, fresh-water availability, and biological diversity, particularly in vulnerable regions (Watson *et al*., 1998).

Global environmental problems are addressed by a range of individual instruments and conventions—UN Convention on Climate Change, Convention on Biological Diversity, Convention to Combat Desertification, and Forestry Principles. Each of the instruments focuses on a specific issue and has its own defined objectives and commitments, with the exception of Forestry Principles, which has no binding legal agreement. A great deal of interaction exists among the environmental issues that these instruments address, and there is also a significant overlap in the implementation of the instruments. They contain similar requirements concerning (UNDP, 1997):

- common, shared, or co-ordinated governmental and civil institutions to enact the general objectives;
- formulation of strategies and action plans as a framework for country-level implementation;
- collection of data and processing information;
- new and strengthened capacities for both human resources and institutional structures; and
- reporting obligations.

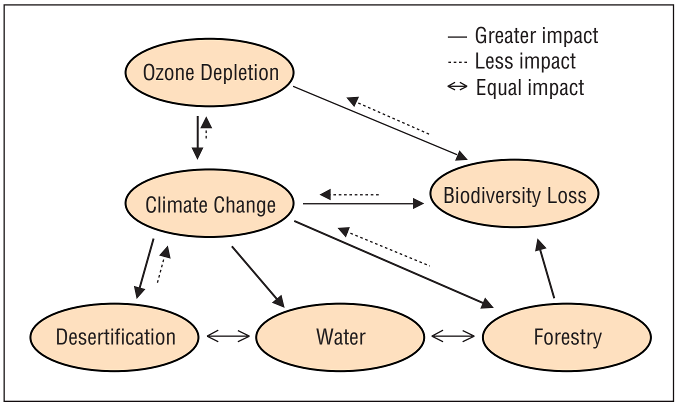

Figure 10.5: *Linkages among environmental issues (Watson et al., 1998).*

Table 10.4: *Overlapping requirements of the Parties to the Rio agreements (UNDP, 1997)*

	Climate change	Biological diversity	Desertification	Forestry principles
National inventories	Article 4(b)			Principle 12(a)
National and regional action plans	Article 4(b)	"Strategies" Articles 6(a), 6(b)	Articles 9, 10	Principles 3(a), 5(a), 6(b), 8(d), 8(h), 9(c) Article 4(b) and Intergovernmental Panel on Forests (IPF) Proposals for Action
Legislation	Preamble	Article 8(k)	Article 5(e)	Principles 8(f), 13(d)
Research	Article 5	Article 12(b)	Articles 17, 19(b)	Principle 12(a)
Public education	Article 6	Article 13	Articles 5(d), 19	Principle 12(d)
Environmental impact Assessment	Article 4(i), 4(d)	Article 14		Principle 8(h)
Public participation	Article 6(i)(a)(iii)	Article 9	Article 19(4)	Principle 2(d)
Exchange information	Article 7	Article 17	Article 16	Principles 2(c), 11, 12(c)
Training	Article 6	Article 12(a)	Article 19	Principles 3(a), 11, 12(b)
Reports	Article 12	Article 26		
Examine obligations; assess implementation	Article 7(e)	Article 23		Principle 12(a)
Report steps to Conference of the Parties (CoP)	Article 12	Article 26	Article 26	

Table 10.4 summarizes the actions and commitments of the parties under the different instruments. The requirements represent a significant burden, especially on developing countries, in terms of human and financial resources. *Table 10.4* illustrates the wide scope for overlaps between the instruments and the risks that their implementation will lead to a duplicative effort.

It is recognized (UNDP, 1997) that global conventions and instruments "can be more efficiently implemented through a greater understanding of the commonalities and overlaps between them and a co-ordinated and harmonized approach to their implementation at the local, national, and international levels. In other words, creating synergy among the instruments and their requirements". Indeed, linkages between instruments provide opportunities to implement them in a mutual-reinforcing manner, avoiding duplication. At least three clusters of activities are likely to gain advantage from potential synergies in implementing the conventions: the development and strengthening of organizational structures, capacity-building interventions, and data collection and information processing.

Implementing the conventions involves the participation of institutional structures with different responsibilities and concerns, their policy agendas are generally limited in scope, and frequently their immediate objectives diverge. Further, environmental issues are in general broadly diffused through different government agencies, endowed with uneven resources in terms of both authority and material resources. This institutional fragmentation, especially in developing countries, results in a lack of co-ordination and duplication of activities in areas where common organizational procedures, flows of information, and a set of coherent individual institutional actions are required for effective policy actions. Reporting to the respective conferences of the parties, setting up appropriate legislation, and formulation and periodical updating of national action plans are stipulated in the conventions. These need to move towards convergence on overlapping issues, seeking consensus, and agree on policy frameworks within which the ultimate goals can be achieved with greater effectiveness. Therefore, the opportunities for synergies can be exploited by enhancing and strengthening linkage mechanisms between institutions, either at the implementation of specific tasks or functions or through the creation of more formal and permanent links between different actors. The types of linkage mechanisms that might be most successful will depend on institutional, political, and economic factors in each specific case.

Concerning capacity building, the conventions and instruments emphasize the dimension of human resource development as a basic condition for addressing the crucial questions related to the evaluation and implementation of policy options. Here, the potential for synergies is considerable since different instruments focus on enhancing the cross-transfer of professional skills to bridge the gap between academic specialization and the job functions of professionals involved in multidisciplinary issues. A variety of complementary and overlapping areas exists in seminars, courses, and workshops on planning tools and methods, policy analysis, and shared fields, reflecting the training needs under each convention.

Data collection and management, analysis and processing of the information, and dissemination are the core of the conventions and instruments. This requires information systems to be set up so that information can be transposed into proper database structures to enable its archiving, retrieval, expansion, and application. Even though each convention addresses a specific set of problems, considerable overlap exists in the data requirements. Information on land uses, forestry, agriculture, infrastructure, and population, among other areas, is common data needed across the instruments. Taking advantage of synergy in information systems avoids redundancy and dispersion in data collection and management, especially in developing countries where the technical competence and expenditure required are beyond the capacity of local agencies.

At the international level the institutions responsible for the various instruments can also support synergy at the national level by co-ordinating among themselves and helping to ensure that participant countries are not burdened by conflicting directives or timing in reporting requirements (UNDP, 1997). Moreover, the scope for linkages among international bodies of scientific expertise, established under different conventions, is evident.

10.3.3 Technology Transfer

Technology transfer has broadly been discussed in the IPCC *Special Report on Technology Transfer* (IPCC, 2000a). The report provides a framework for analysis of the complex and multifaceted nature of the technology transfer process, emphasizing the sustainable development perspective. It examines broad trends of technology transfer in recent years, explores the international political context, discusses policy tools for overcoming key barriers and creating enabling environments, and provides an overview of financing and partnerships. The report also includes sectoral perspectives on the transfer of adaptation and mitigation technologies. These perspectives are illustrated by a wide variety of case studies. This section highlights the main findings of the IPCC report, especially those issues related to the role that the main stakeholders must play in the formulation and implementation of policies that facilitate technology transfer.

10.3.3.1 The View of Technology Transfer

The effectiveness of measures to mitigate or adapt to climate change depends to a great extent on technological innovation and the diffusion of technologies. The transfer and/or diffusion of ESTs across and within countries is now considered a major element of global strategies to achieve climate stabilization and support sustainable development. At the same time, it is recognized that transferred technologies must meet the needs and priorities of specific local circumstances.

The term technology transfer is interpreted by some as a one-time transaction that maintains the dependency of the recipient. Some analysts therefore prefer the notion of technology co-operation or technology diffusion, which is seen by them as reflecting a process of technical change brought about by dispersed and uncoordinated decisions over time. Others still may see technology transfer as a two-way learning process that might more appropriately be called technology communication. According to the definition used by IPCC (2000a), “technology transfer encompasses the broad set of processes that cover the flows of knowledge, experience, and equipment for mitigating and adapting to climate change among different stakeholders. These include governments, international organizations, private sector entities, financial institutions, NGOs and research and/or education institutions. It comprises the process of learning to understand, utilize, and replicate the technology, including the capacity to choose it, adapt it to local conditions, and integrate it with indigenous technologies.” Technology transfer will therefore be used as a broad term including all aspects mentioned above.

While technology transfer is now a common feature of all sectors of human activity, some features are unique to the area of climate change, including:

- scale, both in terms of geography, which may involve all countries of the world, and the number of technologies, which could easily run into the thousands;
- number of persons that might benefit from the success of these efforts, since the whole world is expected to be the beneficiary; and
- payback periods for the R&D expenditures, which may be too long to be of interest to the private sector.

These features determine technology transfer activities that could be evaluated at several levels—international, macro- or national, sector-specific, and project-specific levels—and that could follow different pathways according the interactions among the stakeholders involved in the transfer process. Each pathway represents different types of flows of knowledge, moneys, goods, and services among different sets of stakeholders. Each one has very different implications for the learning that occurs and, ultimately, the degree of technology-as-knowledge transfer that takes places beyond the simple hardware transfers.

10.3.3.2 Technology Transfer: International Aspects

10.3.3.2.1 International Technology Transfer Policy

The legal, economic, and political issues that surround technology transfer have invariably found their place in every international agreement that has anything to do with social, economic, and environmental topics. The Montreal Protocol on Substances that Deplete the Ozone Layer includes several provisions for technology transfer. The Multilateral Fund under the Protocol is a key factor that has facilitated technology transfer to developing countries to comply with the Protocol commitments. Several of the Rio Declaration principles address requirements for states to exchange scientific and technological knowledge and to promote a supportive and open international economic system for the development, adaptation diffusion, and transfer of ESTs. Chapter 34 of Agenda 21, devoted to technology transfer, supports these principles with more detailed proposals for action. The extent to which these proposals have been implemented varies, and debate continues within the UN Commission on Sustainable Development. The Convention on Biological Diversity specifically addresses access to and transfer of technology relevant to the conservation and the sustainable use of biological diversity, including biotechnology.

The UNFCCC requires the parties to the Convention "to promote and cooperate in the development, application, diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases" (Article 4.1.c). The Convention calls developed country parties to take all practical steps to promote, facilitate, and finance, as appropriate, the transfer of, as well as access to, ESTs to other parties, particularly to developing country parties. The importance of technology transfer is also recognized in the Kyoto Protocol of the UNFCC. As further discussed in Section 10.3.3.2.2, flexible mechanisms under the Kyoto Protocol provide strong incentives for technology transfer.

Foreign direct investment (FDI) has proved an effective channel of international technology transfer. Levels of FDI, commercial lending and equity investment all increased dramatically during the 1990s, to the point where official development assistance (ODA) became less than one quarter of the total foreign finance available to developing countries by mid-decade (IPCC, 2000a). The growing role of FDI in technology transfer is supported by various domestic and international developments, including the liberalization of markets, development of stronger domestic legal and financial systems, and tariff reductions under the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). In this context, issues related to intellectual property rights, in particular the Agreement on Trade Related Aspects of Intellectual Property, will play a prominent role in shaping both the flows and intensity of technology transfer in the future. To function effectively, trade and investment require proper enabling frameworks. These include a stable economic system, transparent and equitable legal and/or financial structures, sound environmental laws, uniform non-discriminatory enforcement procedures, respect for local culture, safe and secure environment for workers and/or contractors, and removal of unnecessary barriers to the movement of personnel and materials.

Beyond the issues concerning property rights and the process of opening national economies, changes in the features of new technologies (systematic character, the important role of users, increasing knowledge intensity) have significant implications for technology transfer policy.[19] In particular, many ESTs are still in the early stages of their development and have a comparatively short track record, so private actors may be unwilling to accept the extra risks or costs involved in utilizing new technologies. In general, the spread of proven ESTs that should diffuse through commercial transactions may be limited because of existing barriers. Barriers to the transfer of ESTs arise at each stage of the process, as discussed in detail in Chapter 5. These vary according to the specific context, for example from sector to sector, and can manifest themselves differently in developed countries, developing countries, and countries with economies in transition. Some of the key barriers are summarized in *Box 10.2*. For the success of technology transfer, the parties concerned need to make common efforts to overcome the barriers and create opportunities for the transfer and/or diffusion of technology (Verhoosel, 1997). At present there is no easy answer for overcoming barriers. Measures to be taken depend on the specific barriers and the interests of different stakeholders and are discussed in Chapters 5 and 6.

To improve the enabling environment for technology transfer and diffusion, governments could consider a number of actions such as:

- Enact measures, including regulations, taxes, codes, standards, and removal of subsidies, to internalize the full environmental and social costs and reduce unfair commercial risks.
- Reform legal systems. Uncertain, slow, and expensive enforcement of contracts by national courts or international arbitration, and insecure property rights can discourage investment.
- Reform administrative law to reduce regulatory risk and ensure that public regulation is acceptable to stakeholders and subject to independent review.
- Protect intellectual property rights and licenses, and ensure the active use of patents.
- Encourage financial reforms, competitive national capital markets, and international capita flows that support FDI. Governments can expand financial lending for ESTs through regulation that allows the design of spe-

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[19] An overview of international technology transfer mechanisms is given in Radosevic (1999).

Box 10.2. Main Barriers to Transfer of Environmentally Sound Technologies (IPCC, 2000a)

- Lack of full-cost pricing, which internalizes environmental and social cost.
- Poor macroeconomic conditions, which include underdeveloped financial sector, trade barriers (high tariffs and/or quantity controls), high or uncertain inflation or interest rates, uncertain stability of tax and tariff policies, investment risk.
- Risk of change from existing technology to application of new technology, especially risk aversion and business practices in financial institutions.
- Lack of data, information, knowledge, and awareness regarding the availability, characteristics, costs, and benefits of ESTs, especially in the case of "emerging" technologies.
- Lack of markets for ESTs because of lack of confidence in economic or technical viability.
- High transaction costs of obtaining information, negotiating, contracting, and enforcing contracts.
- Lack of vision about and understanding of local needs and demands.
- Low private sector involvement because of lack of access to capital, in particular inadequate financial strength of smaller firms to manufacture, purchase, and install new ESTs.
- Insufficient human and institutional capabilities.
- Lack of supporting legal institutions and frameworks, including codes and standards for the evaluation and implementation of ESTs.
- Low, often subsidized, conventional energy prices that result in disincentives to adopt energy-saving measures and renewable energy technology.

cialized credit instruments, capital pools, and energy service companies.

- Simplify and make transparent program and project approval procedures and public procurement requirements.
- Promote competitive markets, liberalize trade policies, and make investment policies transparent.
- Encourage national markets for ESTs to facilitate economies of scale and other cost-reducing practices.

10.3.3.2.2 Mechanisms for Technology Transfer

Technology intermediaries are needed to reduce barriers to technology transfer associated with information, management, technology, and financing. These operate between users and suppliers of technology and help to create links within networks and systems (through bridging between institutions), and encourage interaction between the system. They also assist with undertaking research, evaluation, and dissemination tasks. ODA programs mechanisms for technology transfer under the UNFCCC, and multilateral development banks (MDBs) can play a significant role in strengthening national institutional and organizational structures for technological development and innovation.

The 1990s have seen broad changes in the types and magnitude of international financial flows that drive technology transfer (IPCC, 2000a; French, 1998). ODA decreased and fell below the committed levels (OECD, 1999a). However, it plays an important role in technology transfer, especially for the sectors and areas that are commercially less attractive to FDI, such as forestry, public health, agriculture, and coastal zone management (OECD, 1997). Moreover, ODA is still critical for the poorest countries, particularly when it is aimed at development capacities to acquire, adapt, and use foreign technologies.

MDBs have become aware of the role they can play in helping to mobilize private capital to meet the needs of sustainable development and the environment, and of the potential to use financial innovation to encourage environmental projects and initiatives. The World Bank has developed a number of initiatives with potential support for environmental technology transfer. An important new initiative is the Carbon Investment Fund, which will provide additional finance for CO_2 mitigating projects in return for carbon offsets. Other MDBs, such as the regional development banks in Africa, Asia, Latin American, and the Caribbean region, can also play an important role in developing systematic approaches to create enabling environments for technology transfer, including South–South technology transfer.

The Global Environment Facility (GEF), the financial mechanisms of the UNFCCC, is a key multilateral institution for the transfer of ESTs (Anderson, 1997). Although this is of a modest scale in terms of total investment and mainstream investment flows, GEF-supported projects are especially significant for renewable energy technologies, such as wind, solar thermal, solar photovoltaic home systems, and geothermal[20].

The Kyoto Protocol mechanisms, in particular the project based Joint Implementation (JI) and Clean Development Mechanism (CDM), can increase technology transfer. CDM and JI can provide financial incentives for ESTs and influence technology choice. As voluntary mechanisms, they require co-operation among developed and between developed and developing country parties, as well as between governments, private

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[20] From 1991 to 1998, GEF approved grants of in total US$610 million for 61 energy efficiency and renewable energy projects in 38 countries. An additional US$180 million in grants has been approved for climate change projects (IPCC, 2000a).

sector entities, and community organizations. Project-based crediting can lead to tangible investments and to the development of local capacity to maintain the performance of these investments. These investments could incrementally assist developing countries to achieve multiple sustainable development objectives, such as economic development, improvement of local environmental quality, minimization of risk to human health by local pollutants, and reduction of GHGs. Much about the design and governance of the CDM, however, remains to be resolved. There is a need to design simple, unambiguous rules that ensure environmental performance in the context of sustainable development, while also favouring investment. The multilateral oversight and governance provisions of the CDM, and the project-basis transactions, will raise the transaction cost of investment in CDM projects as compared to the cost of mitigation through other means. Chapter 6 discusses these aspects in more detail.

10.3.3.3 Technology Transfer: National Aspects

10.3.3.3.1 Research and Development: Supply Side

Research and development (R&D) is a process of forming new ideas and transforming them into products and services. Technology capacity at both the assessment and replication stages of the technology transfer process have to be underpinned by R&D. Central to this process are national systems of innovation and international co-operation between public research institutions and private-sector entities in R&D. Governments have been investing for three decades in R&D for ESTs in the energy sector. There may be a case for seeing whether results from this process have been used and disseminated sufficiently. Developing countries' R&D efforts are often adaptive, following externally developed technology, which suggests the need for additional resources to develop indigenous innovative capacity. The activities at all stages of technological development and implementation are necessary to attain short-term and long-term technical results (Elliot and Pye, 1998). In the field of climate change, R&D of mitigation and adaptation technologies can reduce the costs of implementation of mitigation and adaptation measures, and provides decision makers with viable alternatives in the formulation of response strategies to climate change.

The process of technological innovation includes not only research and development, but also innovation in the design of products, technological processes, and manufacturing, and innovation in management and market exploration. The private sector has played an important role in the development of energy-efficiency technologies, and is becoming increasingly active in developing renewable-energy technologies (Forsyth, 1999). The bulk of R&D and technology transfer in the energy sector is mainly driven by oil, natural gas, and power supply companies. Other energy supply technologies, such as coal, nuclear, and renewable sources, are often dependent on governments to preserve or increase their presence in the market. Governments can play an important role in R&D as follows:

- establish a National System of Innovation—institutional and organizational structures to support technological development and innovation[21];
- build and strengthen scientific and technical educational institutions and modify the form or operation of technology networks;
- guide the advancement in science and technology and the direction of investment through industrial and technological policies, and provide suggestions and consultation to enterprises;
- encourage enterprises to increase investment in R&D of ESTs through effective policies and create a favourable environment for the innovative activities of enterprises;
- make efforts to increase R&D investments through the governmental budget to accelerate the formation of diversified investment and financing systems, including different kinds of loans;
- give policy support to R&D to encourage the development of innovative technologies and products in the field of climate change, including preferential tax policies, import and export tax policies, and government procurement policies;
- develop modalities for the transfer of public owned or supported ESTs;
- provide funds for licensing of patented ESTs entities to encourage the private-sector to transfer ESTs they own to developing countries.

10.3.3.3.2 Technology Transfer: Demand Side

With the tendency towards globalization and closer integration of most countries in the world economy, countries generally have two sources of technologies: they can either develop their own technologies or procure technologies from other countries, adopting and developing them to fit the specific circumstances (Ding, 1998). When technology transfer is carried out between developed and developing countries, it is important to build up a mutual understanding. Developing countries not only need technologies relevant to climate change mitigation, but also those that are able to generate economic benefits and promote social and economic development, recognizing differences in social aspects (such as tradition and customs).

Besides the common problems of climate change, many developing countries are facing the challenges of poverty eradication and economic development. Technology development and technology transfer are effective mechanisms in alleviating these problems. The introduction of technologies will help to reduce the cost and shorten the time of technological development. For developing countries, the transfer and diffusion of appropriate technologies plays a key role in taking measures to mitigate and adapt to climate change, while pursuing the goal of sustainable development (Xu, 1998).

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[21] National Systems of Innovation also have a broader role in creating an enabling environment for the transfer of ESTs (see IPCC, 2000a).

The scope of technology transfer should not be limited to the technology itself. The enabling environment of the technology should also be included. If technology transfer is to bring about economic and social benefits, local capacities to handle, operate, replicate, and improve the technology on a continuous basis must be taken into account, as well as the institutional and organizational circumstances. There is little developmental benefit in a technological initiative that remains confined within a very narrow sphere of influence with scarce possibilities of replication on a significant scale and without decreasing reliance on assistance from abroad. Technology transfer needs to build up strong links between:

- its operational context (tools, machines, equipment, processes);
- the organizational environment (management organization, product operation, and technology infrastructure); and
- knowledge (experience, skills, vocational training, advanced training).

In many cases of technology transfer, much attention was paid to the accelerated introduction of technologies and a high cost was paid to procure expensive technological facilities. However, less attention was paid to the digestion, absorption, and innovation of the introduced technologies, in other words, to the supportive base for technological development. In some cases, technology transfer to increase energy efficiencies achieved a one-off step of efficiency improvement, but disregarded that reversion to previous patterns of efficiency must be prevented and failed to ensure the basis for a continuing and self-sustained path of improving efficiency in the future. In conclusion, the process of development, application, and dissemination of technologies, and their accelerated commercialization, is not simply a technical programme. It concerns a wide range of issues, including policy formulation, personnel training, fund raising, and standardization; in general, an array of interlinked factors are related to the sustainability and replication of technological innovation. (Yang and Xu, 1998; Zhang, 1998; Xu, 1999).

10.3.3.3.3 Capacity Building

Human and institutional capacity building is required at all stages in the process of technology transfer. Much of the focus on capacity building has been on enhancing scientific and technical skills, capabilities, and institutions in developing countries, as a pre-condition for assessing, adapting, managing, and developing technologies (UNCTAD, 1995,1996).

Successful technology transfer depends to a great extent on the quality of human resources of the recipients. In general, developing countries lack qualified technical personnel and institutions. Therefore, it is important to build up local competence and an infrastructure that can adapt and "internalize" technology into the local specific conditions and traditions. The potential users of new technologies should learn to use the technologies. The process of learning includes demonstration, training, and technical assistance. The local research community could be strengthened so that it can absorb the new science and technology into the local cultural and social fabric. Together with technology transfer, assistance could be provided to train technical personnel.

Information can play a guiding role in technology transfer. Decision making on technology transfer requires information on the current status of technology, research, and development, technical and economic evaluations of the technologies, and knowledge of the commercial sources of technologies. The establishment of information systems is an important component of institutional capacity building. These systems must also include information on technology assessment services, consultants, financial institutions, lawyers and accountants, and technical experts. Local government, industrial associations, NGOs, and communities can work together in the development of these kinds of systems.

In general, small and medium-size enterprises (SMEs) lack the capability and resources to access all the information necessary to make appropriate decisions. Technical support centres could be set up to provide technical assistance to the SMEs. Several developed countries and international organizations have already developed schemes of this type, with significant success. Electronic information networks can accelerate the exchange of information and therefore should be used more extensively. For example, the Greenhouse Gas Technology Information Exchange (GREENTIE), an initiative of the IEA and the government of Japan, aims to combine voluntary action by governments with incentives for private dissemination of technological information (Forsyth, 1998).

10.3.4 Decision-making Frameworks for Sustainable Development and Climate Change

Decision making related to climate change is a crucial part of making decisions about sustainable development simply because climate change is one the most important symptoms of "unsustainability". Indeed, global warming poses a significant potential threat to future development activities and the economic well being of a large number of human beings. Climate change could also undermine social welfare and equity in an unprecedented manner. In particular, both intra- and intergenerational equities are likely to be worsened. Lastly, increasing anthropogenic emissions and accumulations of GHGs might significantly perturb a critical global subsystem—the atmosphere. Policymakers routinely make macro-level decisions that influence both climate change mitigation and adaptation, but are of a broader scope than strategies specifically related to climate change. These decisions relate to economic development, environmental sustainability, and social equity issues—which invariably have a much higher priority in national agendas than does climate change (Munasinghe, 2000). In this context, economic–environmental–social interactions could be identified and analyzed and effective sustainable development policies formulated by linking and articulating them explicitly with climate change policies.

10.3.4.1 Forms of Decision-making

Despite the close links, climate change and sustainable development have been pursued as largely separate discourses. "The sustainable development research community has not generally considered how the impacts of a changing climate may affect efforts to develop more sustainable societies. Global warming is acknowledged as a problem, but is typically leaped over in an effort to push governments towards specific policy responses. Conversely, the concept of sustainable development and the methodological and substantive arguments associated with it are notably absent in the climate change literature" (Cohen *et al*., 1998). Despite the strong synergies between policies oriented to climate change and national development objectives, different ways of thinking in approaching the two problems lead to different social practices and decision-making procedures, which makes it difficult to establish strong working linkages between them.

The main point here is that climate change and sustainable development are rooted in very different disciplines, which results in distinct conceptual frameworks and policy assessments. The dominant natural science approach to climate change has constructed it as an environmental problem, which can be identified and managed objectively by means of scientific rationality. This formulation has resulted in a number of "value neutral" decision-making approaches and methods that represent only the technical dimension of a much more complex set of decision-making problems (Jaeger *et al*., 1998). These are not especially helpful in deciding how to respond politically, because they ignore the human dimensions of the problem and the difficult and locally differentiated politics of responding to it. In contrast, the human-centred sustainable development approach to environmental problems is more politically and geographically sensitive, but it is analytically vague. This makes it difficult to define or implement in practice (Cohen *et al*., 1998).

This distinction does not simply apply to the formalities, but has rather practical consequences on the systems of rules, decision-making procedures, social practices, and role of stakeholders—the institutional arrangements that determine the processes of problem solving and decision making. Different disciplinary perspectives of climate change and sustainable development can be associated with two major streams of institutional arrangements models, characterized as collective-action and social-practice models (Clark, 1998). A collective-action model, which reflects the mainstream thinking of climate policy literature, embodies the rational actor paradigm. Social actors are coherent identities that possess well-defined preference structures and seek to maximize payoffs through a process of weighting the benefits and costs associated with alternative choices in situations that involve strategic interaction. According to this view, "climate change can be decomposed into a conceptually simple (if still practically challenging) problem, for which a rational solution can be constructed and implemented within the existing framework of political power and technical expertise" (Jaeger *et al*., 1998). The role of government institutions, as the relevant actors in the decision-making process, is to co-ordinate regulation through policy instruments to prevent individualistic behaviour from producing outcomes that are worse for all participants than the feasible alternatives under optimal, rational choices (Clark, 1998; Young, 1998).

By contrast, sustainable development is closer to the idea of institutions as arrangements that engender patterned practices, which play a role in shaping the identity of participants and feature the articulation of normative discourses, the emergence of informal communities, and the encouragement of social learning. This category of social-practice institutional arrangements (Young, 1998) directs attention to processes through which actors become enmeshed in complex social practices. These subsequently influence their behaviour through the de facto engagement in belief systems and normative preferences, rather than through conscious decisions about compliance with regulatory rules. From this point of view, control, legitimacy, credibility, and appropriate decision-making processes become crucial issues in the construction of sustainable development practices.

With such dissimilar discourses it is not surprising that climate change and sustainable development have been pursued as two separate agendas for the purposes of policy formulation and action. Moreover, while these issues have achieved a high level of public interest and visibility, climate change is the issue that so far has formally been accepted for serious consideration in government agendas. Sustainable development has not yet been able to translate its ideals into concrete objectives for problem solving and decision making. In this context, scientists are confronted with the urgent task of "reforming the relationship between science research and policymaking" (Rayner and Malone, 1998b). This task implies a twofold effort. First, the sustainable development discourse needs greater analytical and intellectual rigor (methods, indicators, etc.) to make the concept advance from theory to practice. Second, the climate change discourse needs to be aware of both the restrictive set of assumptions that underlie the tools and methods applied in the analysis, and the social and political implications of the scientific constructions of climate change (Cohen *et al*., 1998).

Over recent years a good deal of analytical work has addressed the problem in both directions. Various approaches have been explored to transcend the limits of the standard views of rationality in dealing with issues of uncertainty, complexity, and the contextual influences of human valuation and decision making. Jaeger *et al*. (1998) provide a useful discussion on the various attempts to create new interfaces between scientific rationality and a pluralistic society. As these authors remark, "a common theme emerges: the emphasis on cultural and social realities, which cannot be reduced to individual choices." Now, it is recognized that sustainable development and climate change deal not only with complex and poorly defined goals, but also that the values at stake are plural and conflicting, and even the very nature of each problem is successively transformed in the course of exploration. Problems are no longer seen as external constraints to the social progress, but as issues inherent to the structure itself of societies, so even the idea itself of finding a solution no longer applies, since problems are not solved but managed (Tognetti, 1999). Therefore, the process of integrating and internalizing climate change and sustainable development into national agendas requires new problem-solving strategies in which decision making takes on a new complexion. It becomes a task of finding a partially undiscovered landscape rather than charting a scientific course to an end point. Decisions must be made about which of the systemic possibilities to promote and which to discourage, how to deal with uncertainties, and what risks to take considering irreversible changes and potential bifurcation points. These decisions must be informed by science, but in the end they are an expression of human ethics and preferences, and of the sociopolitical context in which they are made (Kay *et al*., 1999).

In a seminal work, Funtowicz and Ravetz (1993, 1994) provide a fruitful approach to problem-solving and decision-making strategies in terms of uncertainties in knowledge and complexities in ethics. Contrary to the traditional view that science is value-free, these authors claim that in any real problem of environmental management, scientific facts and sociopolitical values are inseparable dimensions. According to the degree of both uncertainty and decision stakes, Funtowicz and Ravetz distinguish three sorts of problem-solving strategies: applied science, professional consultancy, and post-normal science.

When system uncertainties and decision stakes are both low, applied science is able to manage problems by means of standard routines and procedures. Here, problems are regarded as objective states that exist independently of values and perceptions. The existence of one best solution is assumed, and the task of analysts and decision makers is to work out the optimal strategies by searching for the maximum utility among a number of options (Mintzberg, 1994). Since consensus on the problem definition and values at stake are assumed, the proposed solutions speak for themselves, and the implementation just requires their translation from the technical language of scientists to the pragmatic language of policymakers.

Professional consultancy deals with problems for which uncertainties cannot be managed at a technical level, because of the more complex aspects of the problem and because the decision stakes are also more complex, involving both stakeholders and natural systems. In response to the public demand for more inclusive processes, problems are treated as risks, and if techniques and procedures from the applied science are required, judgement becomes a key element in the decision process.

A third sort of problem-solving strategy emerges when uncertainties are of either an epistemological or ethical nature, or when the decision stakes reflect conflicting purposes among stakeholders. In this case, the "puzzle-solving exercises of normal science" are no longer applicable to the resolution of policy issues of risks and the environment. What is required here is an approach that allows:

- management of irreducible uncertainties in knowledge and ethics;
- plurality of different legitimate perspectives; and
- extension of the peer community to all those with a stake in the dialogue of the issue.

These are the elements of an emerging type of problem-solving and decision making known as post-normal science (Funtowicz and Ravetz, 1993).

The main contribution of post-normal science to policy analysis is to assert that when science is applied to policy issues, it cannot provide certainty for policy recommendations; and the conflicting values in any decision process cannot be ignored, even in the problem-solving work itself (Jaeger *et al.*, 1998; Rayner and Malone, 1998b). The epistemological analysis of the approach shows that the insertion of technocratic discourse into a broader social discourse and participation is not only possible, but also necessary to improve the substantive quality of decisions. At the practical level, the post-normal concept lays out a DMF for articulating new institutional arrangements in which power sharing between conventional decision-making agents and extended peer communities is a key element (De Marchi and Ravetz, 1999; Healy, 1999). This is not merely motivated by a "democratic sentiment", but by the conviction that the resultant decisions, although not necessarily economically the most efficient, will turn out to be better decisions, judged by a broad range of competing social criteria (Rayner and Malone, 2000).

10.3.4.2 Public and Private Decision Making

Decision analysis largely addresses both sustainable development and climate change at their most aggregated level as government policy. The implicit assumption of the government as a single decision maker has resulted in scant attention (even neglect) being paid to how government policies and decisions are connected to lower hierarchical levels at which policies must be implemented. This issue raises two interconnected questions: the first concerns the view of the government as a homogeneous and unitary decision-making actor, and the second relates to the links of government policies to everyday decisions by concerned stakeholders.

Regarding the first question, government structures involved in the decision-making process vary considerably among countries. Some governments have established interministerial committees to co-ordinate sustainable development policies, including climate change strategies, while others have assigned responsibilities to more formal permanent commissions or even to a ministry created specifically to handle sustainable development policies. With many different institutions involved in sustainable development issues, considerable confusion often exists regarding who has the responsibility for policy formulation, where the authority for making day-to-day decisions resides within the government, and how channels of communication and decision making should be achieved between the different actors involved. Institutional articulation remains one of the critical factors affecting the consolidation of an effective decision-making process related to sustainable development. Even if there exist rules and regulations that assign competence, tasks, and responsibilities among the institutions involved, a considerable gap exists between what might be desirable and what, for the most part, is practised.

Concerning the interface between macro-policies and the real decision-making levels, the situation is no more encouraging. It is true that sustainable development and climate change are primarily the responsibility of the government system simply because national economy-wide policies have widespread effects on the regulation of societal processes. As discussed above (Section 10.3.2.2), government policies shape structural changes in the production systems, affect the spatial distribution patterns of population and economic activities, influence behavioural patterns of the population, and regulate interaction with the environment and resource-base system. However, as recognized (Jaeger *et al*., 1998; Rayner and Malone, 2000) all too often, especially in developing countries, the levers of state power have a small impact on or even no connection with the local level, at which policies must be implemented by ordinary people living in face-to-face communities.

Recent tendencies at different levels are emerging as appropriate responses to increase the legitimacy and competence of local communities, associations, movements, and NGOs in the public decision-making process. Increasing concern of local populations directly affected by environmental problems, together with current tendencies towards decentralization and weakening of authoritarian practices, especially in many developing countries, have opened a new political scenario for a more active participation of civil society in the public policy formulation and decision process. Present trends towards reassigning the setting of rules from government to the markets, together with the process of transferring the provision of services from the public sector to private ownership, have redefined the roles of social stakeholders. Within this context, sustainable development policies are no longer seen as a hierarchically, government-controlled chain of commands, but as an open process in which the principles of "good governance"—transparency, participation, pluralism, and accountability—are becoming the key elements of the decision-making process.

Public involvement in decision making is not a completely new phenomenon. For instance, traditional participatory mechanisms, such as public hearings, notice and comment procedures, and advisory committees, have been practised extensively by US government agencies (Beierle, 1998). However, it is only lately that participatory forms of decision making have acquired legitimacy and prominence in environmental issues, mainly because of their complexity, uncertainty, large temporal and spatial scales, and irreversibility (van den Hove, 2000). As discussed in Section 10.3.4.3, innovative mechanisms such as regulatory negotiations, mediations, stakeholder consultation, collaborative decision-making techniques, community-based methods, and others, are currently being applied by governments, institutions, and local administrations, as well as by intergovernmental organizations. Rayner and Malone (2000) conclude that, whether policy innovation and behavioural change are led locally or nationally, "they will be marked by a process of institutional learning that either moves presently peripheral concerns about climate change to the core of people's daily concerns or, at least, palpably and convincingly links climate policies to these everyday concerns."

10.3.4.3 Participatory Forms of Decision-making

A substantial body of work on participatory approaches to the decision making process has emerged in the 1990s. Theoretical roots of this resurgence originate in the Frankfurt School of Critical Theory and, more concretely, in Habermas' ideas of discursive ethics (Habermas, 1979; O'Hara, 1996). Discursive ethics views rationality as a social construction, inseparably linked to and informed by the human experience of a social, cultural, and ecological life world, which constitutes the context of human experience. It presupposes no norms other than the acceptance of a reasoned, reflective, and practical potential for discourse: that is, the mutual recognition and acceptance of others as "response-able" subjects (O'Hara, 1996). The main contribution of discursive ethics is to offer a conceptual framework for making visible the hidden normative assumptions, behaviours, and motivations that influence de facto decision-making and valuation processes.

Despite the resurgence of interest in public participation, no widely accepted consistent method has emerged to evaluate the success of individual processes or the desirability of many participatory methods. Diverse perspectives together with country-specific conditions favour different forms of participation. In most developed societies, participatory discourse has been motivated by public concerns on the rigid and constraining forms of technocratic decision-making practices, and their institutionalized forms of bureaucracy and social control. Following Beierle (1998), divergent models of the role of civil society in decision making arise from differences of view on the nature of democracy. A managerial perspective acknowledges public preferences as vital to the managerial role of democratic institutions in identifying and pursuing the common good, but public participation in decision making conveys the threat of self-interested strategic behaviour. Under a pluralistic perspective there is no objective "common good", but a relative common good that arises out of the free deliberation and negotiation among organized interest groups. The role of the government is arbitration among these groups. Lastly, a popular perspective calls for the direct participation of citizens as a mechanism to instil democratic values in citizens and strengthen the body politic. Each view provides different forms of participation: the managerial perspective may favour information flow mechanisms, such as surveys or the provision of right-to-know information; the pluralist perspective prefers stakeholder mediation; and the popular perspective favours citizen advisory groups (Beierle, 1998).

Participatory forms in decision making carry a distinct connotation in developing countries. They are rooted in the idea of grassroots participation, promoted by international development aid agencies since 1990 (UNDP, 1992). The concept is far from new, but in recent years it has received a different connotation. Before, participation was considered as an extension of partnership between governmental institutions and development institutions at the operational level. The scheme was oriented mainly to relieve the state of some of its executorial responsibilities without any effective form of decisional decentralization (Lazarev, 1994). Participatory development as it is envisaged today aims to renew these ideas of partnership, but to give due recognition to the role of local populations by letting them generate, share, and analyze information, establish priorities, specify objectives, and develop tactics (World Bank, 1996). It is viewed as a social learning process within which stakeholders, by generating and internalizing their own aspirations, themselves enable a social change process.

Impoverished and marginalized areas in developing countries have been the main targets for promoting participatory forms of decision making. The rationale is straightforward: these segments of population are generally the less educated and less organized, they are more difficult to reach, and the institutions that serve them are often weak. A range of participatory methods better adapted to work at the field level have been designed to engage and enable the poor to become active actors in development programmes. These include workshop-based and community-based methods for collaborative decision making, methods for stakeholder consultation, and methods for incorporating participation and social analysis into project design. Based on a World Bank (1996) survey of participatory methods, *Table 10.5* summarizes some of relevant participatory tools.

Involving citizens in the decision-making process is not an easy task. It requires careful planning, thoughtful preparation, and flexibility to change procedures on the demand of affected stakeholders. The selection of a supportive and conducive structure for public discourse is essential, not only to gain public acceptance, but also to take advantage of the full potential to articulate well-balanced decisions (Renn *et al*., 1993). Setting aside technical aspects and contextual differences, participatory forms of decision making are viewed as proper mechanisms to achieve broader social goals (Beierle, 1998). These are to inform and educate the public, incorporate public values, assumptions, and preferences into decision making, increase the substantive quality of decisions, foster trust in institutions, and reduce conflict among stakeholders.

10.4 Policy-relevant Scientific Questions in Climate Change Response

10.4.1 Introduction

In this section a selected set of key policy-relevant scientific questions is examined in some detail. It surveys new developments and new results to foster our ability to make critical choices in climate policy, such as striking the right balance between mitigation and adaptation, the timing and location of actions, the costs of actions, and options to reduce and share them. After a brief discussion of the broad climate policy portfolio, the focus is on mitigation questions. The issues involved in these policy responses are structured as follows.

What should the response be? What are the most important factors to consider in crafting a short- to medium-term portfolio of mitigation and adaptation actions, and in acquiring information to resolve the large uncertainties? Drawing largely on IAMs, Section 10.4.2 takes a closer look at the first two components.

When should the response be made? The relationship between the timing of various types of mitigation responses, their costs, and their social, economic, technological, and environmental implications, raises a broad array of policy issues. The most important insights are summarized in Section 10.4.3.

Where should the response take place? Closely related to the timing issue, the location of mitigation responses is a multifacetted concern also. While the environmental value of a given amount of unreleased GHG is equal wherever its abatement takes place, there are far-reaching implications of whether and to what extent nations are allowed to use international flexibility instruments. The questions range from cost and efficiency concerns, to incentives for technological development, to implementation and verification problems. Section 10.4.4 summarizes some of the aspects.

Who should pay for the response? The location of the mitigation action can largely be separated from the question of who carries the costs. Numerous guidelines have been proposed for burden sharing. They range from historical responsibility, to various equity principles, to efficiency and international competitiveness concerns. Some fundamental points are reviewed in Section 10.4.5.

Towards what objective should the response be targetted? Current analyses of climate change impacts, adaptations, and mitigation normally cover the range between 450 and 850ppmv CO_2-equivalent concentration or an increase of between 1°C and 6°C in the global mean temperature. Completing the circle that started with the discussion of how the costs and benefits of balancing mitigation and adaptation activities influence the choice of the climate and/or GHG stabilization target, the issue of high versus low levels of stabilization is raised again in Section 10.4.6.

Table 10.5: *Participatory methods and tools (World Bank, 1996)*

Method	**Tools**
Collaborative decision making: Workshop-based methods	*Appreciation–influence–control (AIC)* AIC encourages stakeholders to consider the social, political, and cultural factors, along with the technical and economic aspects, that influence a given project or policy. Activities focus on building appreciation through listening, influence through dialogue, and control through action. *Objectives-oriented project planning (ZOPP)* The purpose of ZOPP is to undertake participatory, objectives-oriented planning that spans the life of the project or policy work, while building stakeholder commitment and capacity with a series of workshops. *TeamUP* TeamUp builds on ZOPP, but emphasizes team building. It enables teams to undertake participatory, objectives-oriented planning and action, while fostering a "learning-by-doing" atmosphere.
Collaborative decision making: Community-based methods	*Participatory rural appraisal (PRA)* PRA is a label given to a growing family of participatory approaches and methods that emphasize local knowledge and enable people to undertake their own appraisal, analysis, and planning. It enables development practitioners, government officials, and local people to work together in context-appropriate programmes. *SARAR* The purpose of this participatory method is to (a) provide a multisectoral, multilevel approach to team building through training, (b) encourage participants to learn from local experiences rather than from external experts, and (c) empower people at the community and agency levels to initiate action.
Methods for stakeholder consultation	*Beneficiary assessment (BA)* BA's general purposes are to (a) undertake systematic listening to "give voice" to poor and other hard-to-reach beneficiaries, thereby highlighting constraints to beneficiary participation, and (b) obtain feedback on development interventions. *Systematic client consultation (SCC)* SCC refers to a group of methods used by the World Bank to improve communication among Bank staff, direct and indirect beneficiaries and stakeholders of bank-financed projects, government agencies, and service providers, so that projects and policies are more demand-driven.
Methods for social analysis	*Social assessment (SA)* Objectives of SA are to (a) identify key stakeholders and establish the appropriate framework for their participation, (b) ensure that project objectives and incentives for change are appropriate and acceptable to beneficiaries, (c) assess social impacts and risks, and (d) minimize or mitigate adverse impacts. *Gender analysis (GA)* GA focuses on understanding and documenting the differences in gender roles, activities, needs, and opportunities in a given context. It highlights the different roles and learned behaviour of men and women based on gender attributes, which vary across culture, class, ethnicity, income, education, and time.

10.4.2 What Should the Response Be? The Relationship between Adaptation and Mitigation

The principal objective of mitigation activities is to reduce the amount of anthropogenic CO_2 and other GHG emissions in order to slow down and thus delay climate change. Ultimately, this is to achieve "stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC, 1993, Article 2). In contrast, climate change adaptation aims to reduce adverse consequences of climate change and to enhance positive impacts, through private action and/or public measures (*Box 10.3*). Adaptation activities include behavioural, institutional, and technological adjustments. They capture a

Box 10.3. Mitigation and Adaptation

Mitigation consists of activities that aim to reduce GHG emissions directly or indirectly (e.g., by changing behavioural patterns, or by developing and diffusing relevant technologies), by capturing GHGs before they are emitted to the atmosphere or sequestering GHGs already in the atmosphere by enhancing their sinks.

Adaptation is defined as adjustments in human and natural systems, in response to actual or expected climate stimuli or their effects, that moderate harm or exploit beneficial opportunities (see IPCC, 2001b)

wide array of potential strategies, such as coastal protection, establishing corridors for migrating species, searching for drought-resistant crops, altering planting patterns, forest management, as well as personal savings or insurance that may cover the damage expected by individuals (Toman and Bierbaum, 1996). Adaptation is a central theme of WGII (IPCC, 2001b).

Whereas mitigation deals with the causes of climate change, adaptation tackles the consequences. As a result, the distribution of benefits from mitigation and adaptation policies is fundamentally different in terms of damage avoided. Mitigation will have only a long-term global impact on climate change damage, while adaptation options usually generate a positive effect in a shorter term. Adaptation activities mainly benefit those who implement them, while gains from mitigation activities accrue also to those who have not invested into the abatement policies. Mitigation is plagued by the free-rider problem and might create severe problems for decision making as opposed to adaptation, in which free-riding is much more limited. Hence, the output of mitigation activities can be viewed as a global public good, while the output of adaptation measures is either a private good in the case of autonomous adaptation or a regional or national public good in the case of public strategies (Callaway *et al*., 1998; Leary, 1999). Mitigation policies at the global scale are efficient only if all major emitters implement their accepted reduction commitments. In contrast, most adaptation policies are carried out by those for whom averted damage exceeds the respective costs (Jepma and Munasinghe, 1998).

What adaptation and mitigation actions have in common is that they both avoid climate change damages. So far the debate about climate change policy has been dominated by emission reduction activities. The strong bias towards mitigation schemes has resulted in a relatively poor incorporation of adaptive response strategies into climate change analysis, although methods on how to evaluate and assess adaptive response strategies have already been elaborated (Feenstra *et al*., 1998; Parry and Carter, 1998). The reasons for this are diverse. Adaptation has been associated with an attitude of fatalism and acceptance. Putting too much emphasis on adaptation strategies might raise the notions that mitigation efforts have little effect, that climate change is inevitable, and/or that mitigation measures are unnecessary. Approaching the climate issue from the adaptive side might inhibit concerted rational action by governments, as adaptation measures are conducted and rewarded locally. Consequently, there is no incentive to participate in international negotiations if a country considers itself to be able to adapt fully to climate change (Pielke, 1998).

Emission reduction is recognized as attacking the immediate cause. However, the political and scientific discussion would certainly gain by broadening it beyond the issue of mitigation, if only because past emissions of GHGs together with their long atmospheric lifetime leave the earth with unavoidable adverse climate change impacts, irrespective of current mitigation actions (see Smith, 1997; Jepma and Munasinghe, 1998; Rayner and Malone, 1998b).

Even if mitigation efforts do succeed, adaptation strategies are considered to be reasonable because ancillary benefits independent of climate change might result (Pielke, 1998). Exploring adaptation strategies and the way in which people in “homes, factories, and fields” can be empowered institutionally and technologically to change their practice of living may, next to the generation of short-term benefits, contribute to substantial emission reductions, as well as to the development of strategies to cope with general aspects of global change and thus improve their ability to flexible (re)action. Hence, bottom-up analysis can be viewed as a necessary complementary tool in examining climate impacts with respect to top-down schemes employed in the derivation of national GHG emission reduction targets conducted by expert groups (Rayner and Malone, 1998a).

It is recognized increasingly that the impacts of global climate change are not determined solely by the physical characteristics of events. They also depend on the society’s ability to adapt to changing patterns of the geophysical environment, as indicated by the analyses of documented impacts of historical climate hazards (Meyer *et al*., 1998). Larger damages and higher losses of life are caused by extreme weather events in poor regions compared to similar events in affluent regions. Thus damages are not only a function of climatic change patterns. They are strongly influenced by economic, institutional, and technical development, which determine the capacity to adapt to changing patterns, as well as by exogenous shifts in socioeconomic conditions, such as population growth (Tol and Fankhauser, 1998).

The challenge is to find the right balance of adaptation and mitigation measures that represents an effective and complementary response strategy to climate change. For this purpose it is important to recognize the potential economic trade-off between mitigation and adaptation strategies. This trade-off entails the use of scarce resources in mitigation activities, like restructuring a nation’s energy system, versus adaptation strategies, like protection against changing flood and/or drought patterns or sea-level rise. More generally, the trade-off implies greater or lesser stresses from climate change to be adapted to, depending on the level of mitigation effort. The question then is to what extent governments should focus on mitigation and adaptation strategies, recognizing that adaptation and mitigation decisions would generally not be made by the same entities. This implies that the search for the best possible combination of adaptation and mitigation strategies is a complex process.

Several approaches from different angles are possible to answer this question. From an economic point of view, the task is to compare the marginal costs and benefits of both strategies, and—in an optimization framework—minimize the overall welfare loss or macroeconomic costs. Following the heuristic principle of precaution would imply precautionary investments in both mitigation and adaptation to hedge against the uncertainties involved in climate change. However, there is little guidance in the discussion of the precautionary approach regarding how to operationalize critical levels of GHG emissions. Furthermore, the success of climate change policy depends on institutional structures and constraints that need to be analyzed with respect to the feasibility of mitigation and/or adaptation strategies.

10.4.2.1 Economic Considerations

From a global optimization perspective, the aim of coping with climate change is to determine the optimal scope and amount of adaptation and mitigation measures and thus to minimize the resultant global welfare loss. In this context, the quantity of adaptation depends on the level of mitigation, but the perceived level and costs of adaptation influence the level of mitigation. The task is then to set the share of mitigation and adaptation costs within the overall costs, which include the residual damage costs (Fankhauser, 1996; Jepma and Munasinghe, 1998). In the IAMs, which use a cost–benefit framework, the optimal mitigation and adaptation levels are theoretically resolved by comparing the marginal costs of further action with the marginal benefits of avoided damage. Many uncertainties characterize this framework, such as sector- and country-specific damage functions, and adaptation options and their costs are largely unknown, especially in developing countries. Assumptions and data behind the mitigation cost functions differ widely as well, as explained in previous chapters.

Integrated studies do not yet explicitly report adaptation costs and possible secondary benefits of adaptation strategies. In fact, they take into account individual market adjustments driven by changes in relative prices and changing consumption, investment, and production decisions to balance the private marginal benefits and costs (private adaptation; Callaway *et al*., 1998). However, most IAMs do not balance the marginal costs of controlling GHG emissions against those of adapting explicitly to any level of climate change. Tol and Fankhauser (1998) give an overview of IAMs and their treatment of adaptation strategies (*Table 10.6*). Tol *et al*. (1998) approximate that about 7%–25% of the estimated global damage costs may be attributed to adaptation activities.

Another observation is that adaptation options are typically analyzed for a given amount of climate change independent of mitigation considerations (Fankhauser, 1996). Here the aim is to find the amount of adaptation necessary to minimize the net damage that results from a given level of climate change. Analysts often include predetermined adaptation options in an ad-hoc manner, and so there is a tendency to underestimate adaptive capacity. These analyses have been widely carried out and are reasonably well understood in the field of agricultural and coastal impacts, at least in some developed countries (Fankhauser, 1995a; Yohe *et al*. 1996; Mendelsohn and Schlesinger, 1997; Mendelsohn and Neumann, 1999).

In general, the integrated analysis of adaptation options is a rather complex process because all socioeconomic trends affect the vulnerability to climate change and vulnerability determines the optimal level of adaptation. Even without adaptation, impact assessments vary depending on the socioeconomic development projected for the future. Studies that examine the avoided damage under different emissions reduction targets (i.e., different costs of mitigation) and compare them with the costs of adaptation options are yet to be developed.

Giving policy advice on the basis of the efficiency concept within the IAM framework is often difficult, partly because IAMs capture only some elements of the potential coping strategies and are, thus, biased towards mitigation activities, and partly because damage estimates still have a rather low confidence (Tol, 1999a, 1999b). Nevertheless, IAMs are a useful tool in exploring the implications of new types of policies. They help to manage scientific knowledge and give insights into the major driving forces for present and future development with respect to social, economic, and ecological structures (Rotmans and Dowlatabadi, 1998).

The critical aspect of the efficiency approach is that it is only partially optimal because the level of climate change, which depends on the level of mitigation, is exogenous (Callaway *et al*., 1998). Thus, this approach does not take into account that the emissions causing climate change are the result of externalities and therefore are not optimal. From this perspective, to correct the emissions’ externality through mitigation is the first answer. However, the need for adaptation measures remains valid because of the adverse climate change effects that are already unavoidable. Strategies that incorporate both mitigation and adaptation are likely to be more efficient for limiting the damages of climate change than strategies that pursue only one or the other form of action.

Table 10.6: *Adaptation in integrated assessment models*

Model	**Adaptation**	**Source**
DICE	Not explicitly considered	Nordhaus (1994b)
RICE	Not explicitly considered	Nordhaus and Yang (1996) Nordhaus and Boyer (1999)
CONNECTICUT	Not explicitly considered	Yohe *et al*. (1996)
SLICE	Not explicitly considered	Kolstad (1994)
AIM	Not explicitly considered	Morita *et al*. (1997)
MERGE 2, 3	Not explicitly considered	Manne (1995)
CETA CETA revised	Not explicitly considered	Peck and Teisberg (1992)
IMAGE 2.1	Land allocation: expansion or contraction and intensification or extensification	Alcamo (1994)
CSERGE(M)	Not explicitly considered	Maddison (1995)
CSERGE(F)	Not explicitly considered	Fankhauser (1995a, b)
FUND 1.5	Induced adaptation	Tol (1996)
PAGE 95	Adaptation as policy variable	Plambeck and Hope (1996)
MARIA	Not explicitly considered	Mori and Takahaashi (1997)
ICAM 2.0, 2.5	Induced adaptation	Dowlatabadi and Morgan (1995)
MiniCAM 2.0	Induced adaptation	Edmonds *et al*. (1994)
PGCAM	Induced adaptation	Edmonds *et al*. (1994)
DIAM	Not explicitly considered	Grubb *et al*. (1995)
FARM	Production practices in agriculture and forestry, land, water, labour and capital allocation	Darwin *et al*. (1996) Darwin (1999)

AIM: Asian-Pacific Integrated Model
CETA: Carbon Emission Trajectory Assessment
CONNECTICUT: Connecticut
CSERGE: Centre for Social and Economic Research on the Global Environmnet
DIAM: Dynamics of Inertia and Adaptability for integrated assessment of climate-change Mitigation
DICE: Dynamic Integrated Model of Climate and the Economy
FARM: Future Agriculture Resource Model
FUND: Framework for Uncertainty, Negotiation and Distribution
ICAM: Integrated Climate Assessment Model
IMAGE: Integrated Model to Assess the Greenhouse Effect
MARIA: Multiregional Approach for Resource and Industry Allocation
MERGE: Model for Evaluating the Regional and Global Effects of greenhouse gas reduction policies.
MiniCAM: Mini Climate Assessment Model
PAGE: Policy Analysis for the Greenhouse Effect
PGCAM: Process Global Climate Assessment Model
RICE: Regional Integrated Model of Climate and the Economy
SLICE: Stochastic Learning Integrated Model of Climate and the Economy

Also, the efficiency criterion is often criticized because economic efficiency is not necessarily the only aim decision makers, economic agents, and governments wants to pursue, and it does not account for ecological systems and subsistence agriculture entirely outside the market sector. Distributional aspects of burden-sharing schemes and culturally determined risk preferences also play an important role in resource-allocation decisions.

10.4.2.2 Precautionary Considerations

In decision making, the precautionary principle is considered when possibly dangerous, irreversible, or catastrophic effects are identified, but scientific evaluation of the potential damage is not sufficiently certain, and actions to prevent these potential adverse effects need to be justified (Jonas, 1985; O'Riordan and Cameron, 1994; CEC, 2000). The precautionary principle implies an emphasis on the need to prevent such adverse effects. It thus acknowledges societal risk preferences, which are, plausibly, that humankind would rather be risk averse than risk neutral or risk seeking if one considers, for instance, future climate-induced loss of GNP (Pearce, 1994; Jaeger *et al*., 1998). Hence, attitudes towards risk play a key role in decision making under uncertainty. However, one might also favour prevention to cure even where one is certain about the damage.

With the precautionary principle, uncertainty about the damage to be incurred does not serve as an argument to delay action. In the face of great uncertainty, a precautionary approach might even result in a more stringent emission-reductions target and/or adaptational response (Cantor and Yohe, 1998).

The evaluation of uncertainty and the necessary precaution is plagued with complex pitfalls. These include the global scale, long time lags between forcing and response, the impossibility to test experimentally before the facts arise, and the low frequency variability with the periods involved being longer than the length of most records (Moss and Schneider, 2000). Some of these uncertainty aspects may be irreducible in principle, and hence decision makers will have to continue to take action under significant uncertainty, so the problem of climate change evolves as a subject of risk management in which strategies are formulated as new knowledge arises (Jaeger *et al*., 1998).

Aspects of uncertainty are associated with each link of the causal chain of climate change, beginning with GHG emissions, covering damage caused by climate change, followed by a set of mitigation and adaptation measures (Jepma and Munasinghe, 1998). In particular, damage-function estimates are prone to low confidence as they involve uncertainty in both natural and socioeconomic systems. To quantify the impact of climate change on flora and fauna needs consideration of many effects because of the complexity of the biological and ecological systems. Similarly, the manner in which humans adapt to climate change is not well known, socioeconomic modules are still at a stage of low disaggregation, and damage as a function of vulnerability, adaptation and time-dependency is poorly understood (Tol *et al*., 1998; Tol, 1999a, 1999b).

However, following the precautionary principle, uncertainty is not an argument for delaying action, as the UNFCCC acknowledges in Article 3.3: parties should "take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures..." (UNFCCC, 1993). Pursuing this principle, mitigation and adaptation measures are to be implemented before full information is available and uncertainties regarding the scope and timing of climate change are resolved. Yet, the question of timing and extent of mitigation and/or adaptation policies remains unquantified by the precautionary principle (Portney, 1998).

10.4.2.3 Institutional Considerations

In contrast to the single-actor paradigm, which assumes that society can be identified with a unique optimizing decision maker, GHG emissions are, in fact, controlled by a multitude of individual agents and multiple decision makers that influence the transformation of individual to collective actions. Thus far, decision analysis has strongly emphasized the most aggregated level of government policy and neglected the multidimensionality of decision-making institutions (Jaeger *et al*., 1998).

Although there are many country-specific differences in the relationships between national, regional, and local governments, most analysts consider local authorities to be the salient political actors. In addition to acting on their own, local governments serve as an interface between citizens and the nation state, and they are in regular contact with members of the community. O'Riordan *et al*. (1998) suggest that, as the need for more effective climate policy emerges, it might be useful to broaden the national response strategy to incorporate the local levels and so stimulate the very effective informal institutional dynamics of individuals and households. The rise in the number of informal networks of co-operation dispersed via schools, universities, religious communities and other social groups is regarded as an important step towards including climate change awareness into people's everyday concerns. This is of great importance, as the individual costs of contributing to climate change are less than the consequent social costs, and thus individual agents generate a changing climate that is socially suboptimal. Becoming aware of the gap between individual and social rationality is assumed to stimulate effective mitigation and adapation measures.

Striking the appropriate balance between mitigation and adaptation will be a tedious process. The need for, and extent and costs of adaptation measures in any region will be determined by the magnitude and nature of regional climate change as a local manifestation of global climate change. How global climate change unfolds will be determined by the total amount of GHG emissions that, in turn, reflects nations' willingness to undertake mitigation measures. Toth (unpublished) points out that balancing mitigation and adaptation efforts largely depends on how mitigation costs are related to net damages (primary or gross damage minus damage averted through adaptation plus costs of adaptation). Both mitigation costs and net damages, in turn, depend on some crucial baseline assumptions: economic development and baseline emissions largely determine emission reduction costs, while development and institutions influence adaptive capacity.

Different levels of globally agreed limits for climate change (or for atmospheric GHG concentrations, as frequently discussed), entail different balances of mitigation costs and net damages for individual nations. Considering the uncertainties involved and future learning, climate stabilization will inevitably be an iterative process. Nation states will determine their own national targets based on their own exposure and their sensitivity to other countries' exposure to climate change. The global target emerges from consolidating national targets, possibly involving side payments, in global negotiations. Simultaneously, agreement on burden sharing and the agreed global target determines national costs. Compared to the expected net damages associated with the global target, nation states might reconsider their own national targets, especially as new information becomes available on global and regional patterns and impacts of climate change. This becomes the starting point for the next round of negotiations. It follows from the above that establishing the "magic number" (i.e., the upper limit for global climate change or GHG concentration in the atmosphere) will be a long policy process, hopefully helped by improving science.

Mitigation and adaptation decisions related to anthropogenically induced climate change differ. Mitigation decisions involve many countries, disperse benefits globally over decades to centuries (with some near-term ancillary benefits), are driven by public policy action, based on information available today, and the relevant regulation will require rigorous enforcement. In contrast, adaptation decisions involve a shorter time span between outlays and returns, related costs and benefits accrue locally and their implementation involves local public policies and private adaptation of the affected social agents, both based on improving information. Local mitigation and adaptive capacities vary significantly across regions and over time. A portfolio of mitigation and adaptation policies will depend on local or national priorities and preferred approaches in combination with international responsibilities.

10.4.3 When Should the Response Be Made? Factors Influencing the Relationships between the Near-term and Long-term Mitigation Portfolio

A broad range of mitigation responses can be conceived. However, the bulk of attention, in both the analytical and policy arenas, has been devoted to reducing the emission of GHGs from anthropogenic sources and to removing the CO_2 (the most important GHG) already in the atmosphere by enhancing the biophysical processes that capture it. The timing of these efforts depends partly on the climatic constraints to be observed and on the costs of these actions, which are subject to change over time. Even with an exact knowledge of the timing and consequences of the future impacts of climate change, policymakers will still be faced with difficult choices regarding the implementation of response options. This is because the costs, availability, and associated impacts of future mitigation options are uncertain, and the choices involve trade-offs with important competing environmental and other social objectives. Chapter 8 (Section 8.1.4) discusses the costs of different pathways towards a fixed stabilization objective, and notes factors which would favour a larger proportion of preparatory activities relative to mitigation per se as well as factors that favour early mitigation. This section considers the wider context relating to climate change risks and damages.

Inertia and Uncertainty

Various attempts have been made over the past few years to explore these questions. Arguments that favour a larger fraction of preparatory activities (developing technologies, building institutions, and the like), rather than emission reductions in the near-term mitigation portfolio, include losses from the early retirement of installed capital stock, technological development, the optimal allocation of resources over time (discounting effect), and the carbon cycle premium (Wigley *et al*., 1996). See Chapter 8 for a detailed discussion. *Table 10.7* summarizes the most important arguments brought forward in favour of modest and stringent emissions reduction in the near term.

In addition to those emphasized by Wigley *et al*. (1996; see above), other arguments are proposed that support less stringent near-term emission reductions as well. Most refer to the significant inertia in economic systems. The first argument below is related to the economic lifetime of already installed capital stock. The second points to the possibility of low-cost mitigation technologies becoming available in the future.

Wigley *et al*. (1996) refer to the inertia of the capital stock. Researchers also identified other fields of inertia such as technological developments and lifestyles. The essential point of inertia in economic structures and processes is that it incurs costs to deviate from it and these costs rise with the speed of deviation. Such changes are often irreversible. The costs stem from premature retirement of the capital stock, sectoral unemployment, switching cost of existing capital, and rising prices of scarce investment goods. Emissions reduction in the present influences the marginal abatement cost in the future. The inertia of technological development arises from the path dependence. The capital stock can be divided into three parts. First, end-use equipment with a relatively short lifetime can be replaced within a few years. Second, infrastructure, buildings, and production processes can be replaced in up to 50 years. Structures of urban form and urban land-use can only be changed over 100 years. The demand and supply of goods and services in these three domains are interrelated in a complex way (Grubb *et al*., 1995; Grubb, 1997; Jaccard *et al*., 1997).

Technological Change

In the debate on weaker versus stronger early mitigation, the modelling of technological change and the resultant costs of the available mitigation technologies at any given time has far more influence when there is explicit consideration of damages from climate change. Many models assume an exogenous aggregated trend parameter, the rate of autonomous energy efficiency improvement. Other authors indicate phenomena such as inertia, lock-in, and the diversity of factors that affect the rate of technological development and diffusion. Energy technologies are changing and improved versions of existing technologies are becoming available, even without policy intervention. Modest early deployment of rapidly improving technologies allows learning-curve cost reductions, without premature lock-in to existing, low-productivity technology. Both the development of radically advanced technologies require investment in basic research and incremental improvements in existing technologies (e.g., learning by doing) is needed. Not only will new energy-system technologies be required to stabilize concentrations of CO_2, but also a host of peripheral technologies to distribute, maintain, transport, and store new fuels. On the other hand, endogenous (market-induced) change

Table 10.7: *Balancing the near-term mitigation portfolio*

Issue	Favouring modest early abatement	Favouring stringent early abatement
Technology development	• Energy technologies are changing and improved versions of existing technologies are becoming available, even without policy intervention. • Modest early deployment of rapidly improving technologies allows learning-curve cost reductions, without premature lock-in to existing, low-productivity technology. • The development of radically advanced technologies will require investment in basic research.	• Availability of low-cost measures may have substantial impact on emissions rajectories. • Endogenous (market-induced) change could accelerate development of low-cost solutions (learning-by-doing). • Clustering effects highlight the importance of moving to lower emission trajectories. • Induces early switch of corporate energy R&D from fossil frontier developments to low carbon technologies.
Capital stock and inertia	• Beginning with initially modest emissions limits avoids premature retirement of existing capital stocks and takes advantage of the natural rate of capital stock turnover. • It also reduces the switching cost of existing capital and prevents rising prices of investments caused by crowding out effects.	• Exploit more fully natural stock turnover by influencing new investments from the present onwards. • By limiting emissions to levels consistent with low CO_2 concentrations, preserves an option to limit CO_2 concentrations to low levels using current technology. • Reduces the risks from uncertainties in stabilization constraints and hence the risk of being forced into very rapid reductions that would require premature capital retirement later.
Social effects and inertia	• Gradual emission reduction reduces the extent of induced sectoral unemployment by giving more time to retrain the workforce and for structural shifts in the labour market and education. • Reduces welfare losses associated with the need for fast changes in people's lifestyles and living arrangements.	• Especially if lower stabilization targets would be ultimately required, stronger early action reduces the maximum rate of emissions abatement required subsequently and reduces associated transitional problems, disruption and the welfare losses associated with the need for faster later changes in people's lifestyles and living arrangements.
Discounting and intergenerational equity	• Reduces the present value of future abatement costs (*ceteris paribus*), but possibly reduces future relative costs by furnishing cheap technologies and increasing future income levels.	• Reduces impacts and (*ceteris paribus*) reduces their present value.
Carbon cycle and radiative change	• Small increase in near-term, transient CO_2 concentration. • More early emissions absorbed, thus enabling higher total carbon emissions this century under a given stabilization constraint (to be compensated by lower emissions thereafter).	• Small decrease in near-term, transient CO_2 concentration. • Reduces peak rates in temperature change.
Climate change impacts	• Little evidence about damages from multi-decade episodes of relatively rapid change in the past.	• Avoids possibly higher damages caused by faster rates of climate change.

could accelerate development of low-cost solutions and induces an early switch of corporate energy R&D from fossil frontier developments to low carbon technologies. Chapter 8 presents a discussion on induced technological change.

Intergenerational Equity

Assuming that current GHG emissions are too high from a sustainability point of view, it might be unfair of the current generation to decide to take the benefits related to emissions for themselves and that future generations should carry the burden of reductions. This argument on intergenerational equity is often emphasized to support early emission reduction.

Representation of Damages

An important implication of the debate on spiky versus smooth stabilization paths[22] is that relatively high emissions in the near term, especially for higher stabilization targets, may produce faster rates of climate change in the early 22nd century. There is little reliable information on what kind and how much risk this would pose to some ecosystems and socioeconomic sectors. Nevertheless, it should be kept in mind that paths towards the same ultimate environmental objectives might involve different environmental impacts for several decades.

This line of research investigates whether the choice of emission paths that lead to the same concentration target makes a difference in damages. In nearly all IAMs, climate damages depend on the magnitude of temperature change, but not on its rate. Experts point out that, because of the difficulties or higher costs of adaptation in some impact sectors, net damages could be higher for a relatively faster climate change. Moreover, some large-scale geophysical systems, like ocean circulation, may also be sensitive to the rate of temperature change (see IPCC, 2001a). To explore the former issue, Tol (1996; 1998a) used the Climate Framework for Uncertainty, Negotiations and Distribution (FUND) model for different damage functions and conducted an extensive sensitivity analysis with respect to the discounting rate, the power of the damage function, the optimal temperature for the level variant, and memory of damages in the rate variant. The results are ambiguous, but the flat path (early mitigation) is preferable in a significantly larger number of cases. This entails, for example, early reductions for discount rates of 0% and 3%, but not for 10%. If the optimal temperature increase exceeds pre-industrial levels by 3°C, early reduction is not required. Tol finds that impact costs for the spiky path are typically less than 20% higher than those of the smooth path. However, the differences are larger when impact costs also depend on the rate of change, when the exponent of the damage function is higher, and when the rate variant includes memory of damages.

Uncertainty with Respect to the Stabilization Target

Looking beyond the question of optimizing the emission path towards a specific concentration level, the main problem is that we do not know today what will be the desirable stabilization target. This kind of uncertainty, the expectation that it will be resolved over time, and the sequential nature of making mitigation decisions supports the arguments for timing mitigation actions in a context of uncertainty, raising various issues including that of inertia. From this perspective, it may be wise to prepare the ground now for possibly deep and fast emission reductions if resolution of the uncertainties would indicate that drastic climate protection measures are necessary, rather than rush towards an uncertain target now by taking an expensive path.

Some models focus on the problem of near-term mitigation measures under long-term uncertain concentration targets, when the capital stock is inert. In these models, the equation for mitigation costs incorporates—beside the common permanent costs—an additional term to represent the transition costs, which are indicators for the inertia of the system. The costs in this field are typically calculated by comparing paths of immediate and of delayed reduction (usually 20 years). The latter is an approximation to the spiky path. In models that incorporate only one production sector, costs depend on the inertia of the system, the delay of reduction measures, and the concentration targets. For a concentration target of 450ppmv, mitigation costs may rise by 70% if the inertia is high (50 years characteristic time), compared to the lower (20 years) inertia of an increase by 25%–32%. The transition costs are more important than the permanent costs until 2050, with a maximum of 1.4% of Gross World Product (GWP) in 2040 and decline to zero until 2070. With respect to uncertain concentration targets, the results are most sensitive to inertia. Emissions reduction are double those of corresponding cases with a certain concentration target; for example, 9%–14% compared to 3%–7% in 2020 under a 550ppmv concentration goal (Ha-Duong *et al*., 1997; see also Grubb *et al*., 1995; Grubb, 1997). In a sectorally disaggregated model with two sectors of different inertias, the abatement levels are roughly the same, but the cost burden lies primarily in the more flexible sector. The costs are higher and the differences are more distinctive in the delayed cases compared to the immediate control cases. The sensitivity decreases with the concentration target. Analysts, however, warn that such models and results are still preliminary.

Possibilities to Reduce Near-term Costs

Chapters 8 discusses various possibilities to capture low-cost options, such as revenue recycling, integration of climate with non-climate policies to achieve ancillary benefits, and the availability of no regrets options. Such possibilities would be in favour of near term actions. For example, revenue recycling has been proposed as one instrument to reduce the costs of, and thus in support, of near-term emission reductions. In addition to the environmental considerations, this argument relates to the numerous distortions from taxes and subsidies in virtually all countries. Economy-wide effects of carbon taxes, and especially the double-dividend issue, are highly debated. Much enthusiasm has been given to “green taxes”, such as the carbon tax, which might reduce the inefficiency of the current tax systems and lead to environmental improvements. Recent analyses show that the ultimate fiscal effect of substituting carbon taxes for other distortionary taxes is roughly neutral (Nordhaus, 1998), but the actual sign depends on the original size of the distortions in the economy. It may be positive in economies with highly distorted tax systems and hence confirm the double dividend hypothesis (see Chapter 8). It is likely to be negative in economies with less pre-existing distortions. In either case, revenue-recycling policies dominate other

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[22] In a “spiky” emissions trajectory the emissions follow the baseline before declining sharply in order to meet a concentration stabilization target, while in a “smooth” trajectory the emissions diverge from the baseline early, allowing a more gradual decline of emissions eventually.

measures considerably. Goulder (1995) and others report about 30%–50% reductions in the cost of regulation, and many European studies find cost reductions over 100%.

10.4.4. Where Should the Response Take Place? The Relationship between Domestic Mitigation and the Use of International Mechanisms

Inquiries into the options and costs to reduce GHGs, especially CO_2, emissions indicate that the costs of reductions vary substantially across sectors in any given national economy and, perhaps even more significantly, across countries. This implies that for uniformly mixing pollutants like GHGs the costs of achieving any given level of environmental protection could be reduced if emission reductions were undertaken at locations where the associated costs are lowest. The concept has become known as "where-flexibility" in the climate policy literature. An institutional setting is required to exploit the opportunities of where flexibility, which involves a great variety of private and public decision-makers who originate from different cultures, represent different constituencies (if any), and live in systems with different social norms. Where-flexibility entails linkages both to other international agreements (GATT, Second European Sulphur Protocol, etc.) and to the legal systems of individual nations. As a result of its effects on relative prices, the choice between the international or domestic strategy also affects technological change.

In principle, two different mechanisms achieve where-flexibility: allowances and credit baseline. In the case of allowances, each participant starts with an initial endowment of pollution rights distributed by the government or through an auction. Emission rights must cover each unit of emission. This system has the character of emissions trading. Under a credit-baseline system, each participant has a baseline (i.e., a counterfactual, hypothetical emission trend) at the country, sector, or project level. Some measures are undertaken to reduce emissions. The difference between the baseline and the factual emissions is credited by an institutional body and can be traded. This system has the character of emissions reduction production.

The Kyoto Protocol contains three instruments to make use of where-flexibility: IET embodies the allowance system, while CDM and JI reflect the credit-baseline system. The Kyoto Protocol on IET allows Annex I parties with commitments listed in Annex B to trade emission allowances during the commitment period. As for JI, Article 6 declares that Annex I parties with commitments listed in Annex B are allowed to transfer or acquire emission reduction units that result from projects during the commitment period (the reduction units are specific to countries; these parties have national baselines). Finally, CDM as defined in Article 12 implies that, starting in 2000, Annex I parties listed in Annex B are allowed to acquire certified emission reductions from projects within the jurisdictions of non-Annex I parties.

Three general principles operate behind these arrangements:

- first, voluntarism indicates the freedom of contracting, i.e., the quantity-price combinations of exchange;
- second, supplementarity signifies the responsibility of Annex I parties to fulfil part of their commitments within their own jurisdictions; and
- third, additionality means that projects in CDM and JI have to be additional relative to the course of events in their absence (i.e., it must be decided what would happen anyway and what constitutes an additional project).

Ample attention has been paid to formulate principles for the design of where-flexibility instruments at the national and international level. The principles in the literature (Michaelowa, 1995; Watt *et al*., 1995; Carter *et al*., 1996; Matsuo, 1998, Matsuo *et al*., 1998; OECD, 1998; Ott, 1998; EC, 1999) include:

- Environmental effectiveness. All units traded should be backed by sound data and verifiable emissions reductions; the use of the mechanisms is a means to achieve emission commitments agreed under the Protocol and the mechanisms should be designed to improve environmental performance and compliance with these commitments.
- Economic efficiency. This includes the cost-effectiveness of the emission reductions required by the Protocol, and over the longer term helping the community of nations to address climate change in a least-cost manner. It also requires the mechanisms to be administratively feasible, such that they do not impose excessive transaction costs on market actors. Economic efficiency will also improve if the market for trading and crediting is accessible to a wide range of potential players.
- Equity. While the main issue of equity under the Kyoto Protocol is the determination of assigned amounts or emission targets, the design of the implementation mechanism must also be perceived as equitable. Implementation of the mechanisms should not give an unfair advantage to any party or group of parties to the disadvantage of others (procedural equity). It should also allow new entrants over time.
- Credibility. Only a credible market mechanism should be used by the parties and will be accepted by the public. A mechanism of low credibility might be a source of various coalition formations at the negotiations and might undermine the will to comply with the commitments.

In creating a regime for flexible instruments, perhaps the most important lesson about multilateral agreements of the past two decades is that large and apparently "perfect" constructions have rarely been implemented quickly. Quite the contrary, the most successful examples of international regime building are based on a "piecemeal" approach, that is the stepwise evolution of political and legal mechanisms (Ott, 1998). For current DMFs, this might lead to a strategy with several phases that bring together the national and international levels at the speed of progress in international regime building (Holtsmark and Hagem, 1998). This would involve a two-stage game for IET (Ott, 1998), with a "twin cycle system" for JI (Heller, 1995) that focuses on the learning process in creating an international regime for JI.

There are some new and important factors to consider in the design of the instruments (see Ott, 1998). The economic and ecological dimensions of climate change and its mitigation affect different constituencies, sectors, and cultural values of the parties. Stakeholders range from states and international organizations to private companies and NGOs. Incentives motivate both private and governmental participants to report the highest possible baselines of GHG emissions to secure the largest amount of certified reduction credits. However, other processes create the opposite incentives.

The implementation of these instruments can be seen as a further step towards a more flexible and market-oriented policy in international environmental policy, and as an extension of national instruments to the international level. At the national level, some experience has already been accumulated with emissions trading, such as the Emission Trading Program under the US Acid Rain Program, the Los Angeles Regional Clean Air Incentives Markets, and the Norwegian Sulphur Trading programme introduced in 1999. Actual experience is much thinner internationally. Examples of the possibility for emission trading include the Montreal Protocol intended to curb CFC emissions that deplete the ozone layer and the United Nations Economic Commission for Europe (UNECE) Sulphur Protocol.

Many plausible arguments support the use of international mechanisms, as outlined below.

Static Eficiency

This argument is related to the positive allocative effects caused by trade. The argument is fundamentally dependent on the assumption of differences in the marginal reduction costs between countries in a well-defined market. This might lead to gains arising from trade for both sides. Trade reduces the overall costs of compliance with any specified set of internationally accepted reduction targets. Lile *et al*. (1999) and Edmonds *et al*. (1996) find the rationale for Annex I countries is that reduction costs in developing countries are much lower than their own. Ellerman *et al*. (1998) and Holtsmark and Hagem (1998) arrive at similar conclusions. However, some bottom-up, project-based country studies that quantify national mitigation-cost curves and the consequences (e.g., Jackson (1995); EC 1999)) identify lower mitigation costs in developed countries and thus smaller cost differences internationally. *Table 10.8* gives studies on the costs of Kyoto targets under different flexibility arrangements.

Willingness to Accept Deeper Reduction Goals

This argument is related to the reduction of the overall cost of compliance. If the reduction costs are lowered by the use of international mechanisms, then the nations might be willing to accept deeper GHG-reduction commitments. This argument does not hold in countries with potential hot air when a country's baseline (or projected future) emission is expected to be lower than its entitlement, so that a marketable good (emission permit) is created without the need for any effective reduction effort whatsoever. Nevertheless, members of the so-called "umbrella group", including the USA, Japan, Australia, Russia, and others, have made it clear that the level of commitment they accepted in Kyoto was contingent on the unfettered use of flexible mechanisms. In this sense they have already incorporated the willingness to accept deeper emission reductions in their existing commitments for the first budget period.

Complementarity to Other Goals

By using CDM and/or JI, climate protection can serve other goals such as accelerating socioeconomic and technological development, reducing regional and local pollution, and fostering integration and international understanding (Sun Rich, 1996). (See Chapter 1 for an extensive discussion of climate change in the context of sustainable development and Section 10.3 above on linkages to other issues and international agreements.)

Motivation for Private Institutions

Under JI and CDM, private institutions, such as enterprises and NGOs, are likely to be engaged, with the bulk of reduction measures probably taking place in the private sector. This might lead to a further reduction of mitigation costs, because private institutions tend to operate at higher efficiency than state bureaucracies do.

Technology Transfer

JI or CDM is often only possible if technology is transferred from rich and energy-efficient regions to poor and energy-inefficient countries. This might have the favourable effect that developing countries "leap-frog" over the inefficient development stages previously passed through by the developed countries.

Domestic versus International Strategies

Arguments to support a domestic strategy are often formulated as a critique to an international strategy. Some general criticisms focus on the question whether or not an international strategy is an adequate instrument to achieve the ultimate goal of the UNFCCC, that is stabilizing the GHG concentration. Bush and Harvey (1997) emphasize two key requirements: to sharply constrain GHG emissions in developing countries and to achieve significant GHG reduction in developed countries. The most frequent arguments in support of the domestic strategy entail the following.

Dynamic Efficiency

Technological and social innovation are dynamic processes that can be accelerated through pressure from commitments in the Kyoto Protocol. The international strategy allows devel-

Table 10.8: *Studies on costs of Kyoto targets under different grades of where-flexibility*

In this table the essential results (welfare implications) are presented with respect to achieving the Kyoto targets under different institutional seetings for the use of flexibility instruments. The following features are summarized in the table:

1. Reference and year of publication; footnote says where the reference is available
2. Welfare measure and scenario; the scenarios are not all with respect to the Kyoto-targets and the welfare measure is not the same in all studies
3. Different grades of "where-flexibility"
4. Comments on the study summarizes the most important features of the models used for the study.

Study	***Welfare measure and scenario***	**Different grades**								***Comments***
		No trade	***Double-bubble***[23]	***Less than A1 trade***[24]	***x%-Cap***[25]	***Annex 1 trade***	***More than A1 trade***[26]	***A 1 trade + CDM***	***Full/global trade***	
McKibbin, Shackelton and Wilcoxen (1999)	%-change of GNP per region in 2010; not Kyoto: Stab. at 1990 level	USA: -.5 Jap: -.1 Aus: -2.2 OtherOECD (OOECD): -1.2		*OECD* USA: -.5 Jap: -.3 Aus: -1.5 OOECD: -.9 gain $90 bil[27] US-unilateral reduction: -.6						G-Cubed(Global General Equilibrium Growth Model), fossil fuels only; with monetary effects, no 'no-regret', 8 regions, 12 sectors, no terms of trade, capital flows, 1995$
McKibbin, Shackelton and Wilcoxen (1998)	%-change of GNP per region in 2010; not Kyoto: Stab. at 1990 level	USA:-.3 Jap:-.8 Aus:-2.5 OOECD:-1.4 Chi:0 LDC:+2.7	USA:+.1 Jap:-.1 Aus:-1.3 OOECD:-1.2 Chi:0 LDC:+1.8			USA:-.2 Jap:-.2 Aus:-2 OOECD:-.5 Chi:0 LDC:+1.4			USA:0 Jap:0 Aus:-.7 OOECD:-.2 Chi:-.5 LDC:+.2[28]	
McKibbin, Ross, Shackelton and Wilcoxen (1999)	%-change of GNP per Region in 2010; not Kyoto: Stab. at 1990 level	USA:-.6 Jap:-.5 Aus:-1.6 OOECD:-1.3 Chi:-.1 LDC:+.7				USA:-.5 Jap:-.4 Aus:-.8 OOECD:-.6 Chi:-.1 LDC:+.7			USA:-.2 Jap:-.1 Aus:-.4 OOECD:-.2 Chi:-.4 LDC:0	
Bernstein, Montgomery, Rutherford and Yang (1999)	Hicks Equivalent Variation (HEV), %-change from baseline per region, Protocol costs	USA: -.5 Jap: -.6 EU15: -.4 OOE: -1. SEA: -.2 OAS: .1 Chi: +.3 FSU: -.4 MPC: -1.4 ROW: -.1				US: -.25 Jap: - .25 EU15: -.25 OOE: -.75 SEA: 0 OAS: 0 Chi: +.3 FSU: +4.4 MPC: -1.1 ROW: -.1			US: -.2 Jap: 0 EU15 -.1 OOE: -.4 SEA: +.25 OAS: +.2 Chi: +.25 FSU: -.4 MPC: -.3 ROW: 0	MS-MRT (Multi-sectoral, multi-regional General Equilibrium Model) (GEM), terms-of-trade, capital flows, leakage, 10 regions, 5 energy, 4 non-energy sectors, 1995$

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[23] Tulpulé (1998) defines the double-bubble as EU + EE; McKibbin, Ross, Shackleton and Wilcox (1999) defines it as European-OECD.

[24] If less participants than the Annex 1 countries are assumed (e.g. without USA)

[25] Special Case EU-Cap: purchases or sales of emissions by annex B countries may not exceed 5% of the weighted average of base year emissions and the assigned Kyoto emission budget

[26] If more participants than only the Annex 1 countries are assumed (e.g. India, China)

[27] 2010 - 20 discounted at 5%

[28] non-Annex 1 countries accept commitments consistent with the baseline emissions

(continued)

Table 10.8: *continued*

Study	**Welfare measure and scenario**				**Different grades**					**Comments**
		No trade	***Double-bubble*[23]**	***Less than A1 trade*[24]**	***x%-Cap*[25]**	***Annex 1 trade***	***More than A1 trade*[26]**	***A 1 trade + CDM***	***Full/global trade***	
Bernstein, Montgomery and Rutherford (1999)	HEV	US:-.56 Jap:-.64 EU:-.45 OOE:-.92 SEA:-.18 OAS:-.1 Chi:+.34 FSU:-.42 MPC:-1.39 ROW:-.1			US:-.43 Jap:-.52 EU:-.33 OOE:-.78 SEA:-.13 OAS:-.08 Chi:+.31 FSU:+.05 MPC:-1.26 ROW:-.08[29]	US:-.36 Jap:-.23 EU:-.25 OOE:-.76 SEA:-.04 OAS:-.01 Chi:+.22 FSU:+4.44 MPC:-1.15 ROW:-.08		US:-.32 Jap:-.18 EU:-.20 OOE:-.67 SEA:+.06 OAS:+.09 Chi:+.55 FSU:+3.47 MPC:-.92 ROW:+.01[30]	US:-.14 Jap:-.03 EU:-.05 OOE:-.3 SEA:+.25 OAS:+.19 Chi:+.34 FSU:+.48 MPC:-.36 ROW:+.03	MS-MRT GEM, GTAP4 Database, 10 regions, 3 fuels and electrical sectors, 2 goods
					US:-.34 Jap:-.31 EU:-.25 OOE:-.71 SEA:-.07 OAS:-.05 Chi:+.25 FSU:+2.18 MPC:-1.17 ROW:-.08					Annex-I – B30: 30% ceiling for buyers; this restricts imports of TP
					US:-.35, Jap:-.24 EU:-.24 OOE:-.75 SEA:-.05 OAS:-.02 Chi:+.22 FSU:+4.18 MPC:-1.15 ROW:-.08					Annex-I – B50: 50% ceiling for buyers; this restricts imports of TP
					US:-.43 Jap:-.30 EU:-.30 OOE:-.80 SEA:-.08 OAS:-.05 Chi:+.23 FSU:+4.57 MPC:-1.15 ROW:-.08					Annex-I – S50: 50% ceiling for sellers; this restricts exports of TP
					US:-.39 Jap:-.24 EU:-.25 OOE:-.82 SEA:-.02 OAS:.03 Chi:+.26 FSU:+4.27 MPC:-1.23 ROW:-.03					No Hot Air: The QUELRCS[31] for FSU and EE are set to their baseline values

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[29] Annex I - B10: 10% ceiling for buyers; this restricts imports of TP’s

[30] limit of permit sales by each A1-region to 15% of its total sales under unrestricted global trading

[31] Quantified Emission Limitation or Reduction Commitments

(continued)

Table 10.8: *continued*

Study	***Welfare measure and scenario***				**Different grades**					***Comments***
		No trade	***Double-bubble***[23]	***Less than A1 trade***[24]	***x%-Cap***[25]	***Annex 1 trade***	***More than A1 trade***[26]	***A 1 trade + CDM***	***Full/global trade***	
Cooper *et al.* (1999)	Change in potential output (GDP) in 2010 in %	US:-2.5 (-1.8) Ca:-3.9 Jp:-1.8 (-1.9) Ge:-2.2(-2.4) Fr:-2.2(-2.2) It:-2.3 UK:-1.9 EU:-2.2 Chi:+1.6 Rus:+0.9	US:-1.(-.5) Ca:-1. Jap:-.3(-.3) Ger:-2.2(-4.9) Fr:-2.2(-2.2) It:-2.3 UK:-1.8 EU:-2.2 Chi:+.7 Rus:-1.(+2.5 income)			US:-1.4(-.8) Ca:-1.2 Jap:-.5(-.5) Ger:-.8(-.9) Fr:-.6(-.5) It:-.7 UK:-1. EU:-.7 Chi:+.6 Rus:-1.4 (+4.income)				Oxford Model, Energybased macroeconomic GEM, 6 fuels, 4 sectors, 22 regions
Tulpulé (1998, 1999)	%-loss of GNP	Annex 1: -1.2 Non-Annex I: 0	Annex I: -.3 Non-Annex I: 0			Annex I: -.3 Non-Annex I: 0				GTEM, GTAP3-database, 19 regions, 16 tradeables, S(y)=j(i), transport costs for trade
Brown *et al.* (1999)	% loss of GNP, global	-.8				-.2				GTEM, GTAP 4 –database, 18 regions, 23 tradeables, 3 GHG GWP:1,21,310; technological change rising with GHG-penalty, ref-scen = no policy, 1992 $
Böhringer (1999) (CO_2-emissions in bill. t CO_2)	HEV, % of BAU income	-.2 (28.51)			-.15 (28.74)	-.04 (29.03)				global GEM, GTAP4 and OECD/IEA-data, 7 sectors, 11 Regions
Manne and Richels (1997)	consumption loss 1990-2100 discounted with 5% to 1990 in $ WG1	8.7 tril				5.9 tril			3.2 tril	
	10% cut in 2010	4.4 tril				2.7 tril			1.9 tril	
	WRE	1.8 tril				0.9 tril			0.8 tril	
Manne and Richels (1998)	annual US-Costs, 1990 bill. $ in 2010 (2020)	85 (102)						51 (77), 15 % of potentials available due to complexities of flexibility instruments	23 (45)	MERGE 3.0 (model for evaluating the regional and global effects of GHG reduction policies), 9 regions, leakage, Global Trade (GT) non-AI restricted by baseline bounds,
Manne and Richels (1999b)	Kyoto Forever => K-constraints through 21st c. for AI and baseline for NonAI (no leakage); US GDP loss in bil $	87			(a) 55 (b) 61 1/3 limitation of satisfying Kyoto obligations by AI-countries			49 15 % of potential available	23	(a) buyers market - sellers are price takers (b) sellers market – buyers are price takers
Capros (1998)	costs only for regions and not Kyoto targets (15%), EU			* with 15%						POLES for world level, extensive assessment for EU

(continued)

Table 10.8: *continued*

					Different grades					
Study	***Welfare measure and scenario***	***No trade***	***Double-bubble***[23]	***Less than A1 trade***[24]	***x%-Cap***[25]	***Annex 1 trade***	***More than A1 trade***[26]	***A 1 trade + CDM***	***Full/global trade***	***Comments***
Holtsmark (1998)	% loss of 1990 GDP per country	USA:+.49 Ca:+.51 EU[32]:-.05 DK:+.59 Fin:0 Swe:0 Nor:+1.36 Rus:+.17 OthEIT:-.07 AuNZ:+.24 Jap:+.09 N-AI:+.91				USA:+.48 Ca:+.5 EU:-.07 DK:+.37 Fin:0 Swe:0 Nor:+1.22 Rus:+.16 OthEIT:-.07 AuNZ:+.17 Jap:+.08 N-AI:+.46			USA:+.4 Ca:+.42 EU:-.04 DK:+.25 Fin:0 Swe:0 Nor:+1.26 Rus:-.4 OthEIT:-.27 AuNZ:+.17 Jap:+.07 N-AI:+.42	partial & static ACT, strategic OPEC, 3 regional gas markets, multi GHG, national tax with marginal excess burden to account for double dividend hypothesis, no "no regrets", terms of trade
Holtsmark and Hagem (1998)	Costs in % of 1990 GDP per country, EU targets are differentiated as agreed in June 1998	USA:+.29 Ca:+.46 EU:-.12 DK:+.53 Fin:-.12 Swe:+.08 Nor:+1.23 Rus:-.18 OthEIT:-.15 AuNZ:+.06 Jap-.08: N-AI:+.13				USA:+.27 Ca:+.42 EU:+.15 DK:+.23 Fin:-.11 Swe:+.02 Nor:+1.18 Rus:-.17 OthEIT:-.14 AuNZ:-.36 Jap:-.07 N-AI:+.11			USA:+.18 Ca:+.3 EU:-.11 DK:+.1 Fin:-.1 Swe:-.1 Nor:+1.23 Rus:-.33 OthEIT:+.33 AuNZ:-.12 Jap:-.07 N-AI:+.08	partial & static ACT, strategic OPEC, 3 regional gas markets, multi GHG, national tax with marginal excess burden to account for double dividend hypothesis, no "no regrets", terms of trade
Sands *et al.* (1998)	US Costs; non-Kyoto-Targets, 4 policy scenarios: e.g.: 1990 + 10% (M90+1)	M90:+.2 M90+.1:+.07 M90-.1:+.43 M95:+.07				M90:-.18			M90:-.09	SGM, IEA and Government-data, 7 regions, 9 prod sectors, input sectors, determines global C-tax, hot air
Kainuma *et al.* (1998), (1999)	% GDP loss per region; Asia	USA:+.4 Jap:+.25 EU:+.3 EEFSU:+.2 Chi:+.2 Ind:-.25 Kor:-.55 MEA:+.15	USA:+.3 Jap:+.05 EU:+.4 EEFSU:-2.2 Chi:+.15 Ind:-.15 Kor:-.35 MEA:+.8			USA:+.3 Jap:+.15 EU:+.3 EEFSU:-3.6 Chi:+.2 Ind:-.15 Kor:-.25 MEA:+.65	USA:+.3 Jap:+.1 EU:+.15 EEFSU:-2.7 Chi:+.4 Ind:-.15 Kor:-.35 MEA:+.6[33]		USA:+.2 Jap:0 EU:+.05 EEFSU:-1.7 Chi:+.37 Ind:-.2 Kor:-.3 MEA:+.9	AIM, IEA, GTAP and IMF-data, 21 regions, 7 energy-, 4 non-energy goods,
Mensbrugghe (1998)	% GDP loss in bill. 1985 $	+.7				+.2			+.1	GREEN- A multi-sector, multi-region dynamic general equilibrium model for quantifiying the costs of curbing CO_2 emissions: 12 regions, 4 activities, autonomous energy efficiency improvements (AEEI), backstops, terms of trades

(continued)

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[32] EU targets are differentiated as agreed in June 1998.

[33] Annex I + China and India

Table 10.8: *continued*

Study	Welfare measure and scenario	No trade	Double-bubble[23]	Less than A1 trade[24]	Different grades x%-Cap[25]	Annex 1 trade	More than A1 trade[26]	A 1 trade + CDM	Full/global trade	Comments
Richels *et al.* (1996)	20% below 1990 emissions until 2010 and the stab. emissions at his level; Annex 1 countries; trill. 1990 US$, OECD, GDP loss CETA EPPA MERGE MiniCAM	OECD:+2 NOECD:+.3 OECD: +5.2 NOECD:+1.1 OECD:+2 NOECD:+.3 OECD:+1.5 NOECD:-.1							OECD:+1.3 NOECD:-.7 OECD: +2 NOECD:-.5 OECD:+1.1 NOECD:0 OECD:+.5 NOECD:-.2	
Nordhaus and Boyer (1999)	RICE-98; GDP loss in 1990$	US: 84 bil. Jap: 38 bil. EU: 65 bil. CANZ: 19 bil.				US: 60 bil. Jp: 19 bil. EU: 36 bil. CANZ: 11 bil.			US: 21 bil. Jap: 6 bil. EU:15 bil. CANZ: 4 bil.	RICE-98; 13 regions, no trade in goods, IAM;
Tol (1999a)	consumption loss 1990-2100, discounted with 5% to 1990, in trill. $; target:Kyoto forever	No-AI: -.15 OECD: 2.75 EEfSU: .75	No-AI: -.2 OECD: 2.25 EEfSU: .6		lim. purch:[34] No-AI:-.15 OECD:2.45 EEfSU: .5 lim.sale:[36] No-AI: .8 OECD: 1.9 EEfSU: -.15 lim. both: No-AI: .65 OECD: 2.15 EEfSU: -.15	No-AI: -0.15 OECD: 2.1 EEfSU: .6	No-AI: .5 OECD: 1.25 EEfSU: .45[35]		No-AI: .45 OECD: .9 EEfSU: .35	Framework for Uncertainty, Negotiation and Distribution (FUND)-IAM; 9 regions, dynamic damage
Kurosawa *et al.* (1999)	GDP loss in bill. 1990 $ in 2010	US: Jap: EU: 90 CANZ:				US: Jap:10 EU: 90 CANZ:			US: Jap: EU: 63 CANZ:	GRAPE-IAM, 10 regions
Criqui *et al.* (1999)	Total Cost (GDP)in 1990 $ in 2010	56419 Mio. (0.11)			only for US and Asian countries	16 583 Mio. (0.03)			5808 Mio. (0.01)	POLES
Ellerman *et al.* (1998)	Total Cost in bill. 1985 US$	+120				+88			+11	Emissions Prediction and Policy Assessment (EPPA)-Model
Zhang (1998)	Reductions in total abatement costs compared to the no-trade-	:		[37]USA:81 Jap:91 EU:2.3 OOECD: 33.5 OECD:82.4	[38]USA:63.7 Jap:71.9 EU:39.2 OOECD:70.8 OECD:66 [39]USA:81.1 Jap:77.4 EU:19.1 OOECD:68.8 OECD:79.6				USA:85.2 Jap:93.1 EU:0.2 OOECD:45.3 OECD:86.5	12 regions, 6 GHG

[34] Maximum Emissions are 110% of allotment (= commitment); i.e. restricts the quantitiy bought from abrought

[35] Annex 1 plus Asia

[36] 90% of allotment must be emitted => this restricts the quantity sold to others

[37] No Hot Air: Trading in Hot-Air is not allowed, indicating that any effectuated trading in GHG emissions must represent real emission reductions

[38] EU-Caps

[39] 50% reduction from BAU scenario: The Maximum allowed acquisition from all three flexibility mechanisms are limited to 50% of the difference between the projected baseline emissions and the Kyoto targets in 2010

oped countries to lower this pressure and, as a result, less innovation would occur. Instead of innovation, inefficient technology would be exported to developing countries. This argument is strongly related to the endogenous growth argument. The problem from the scientific point of view is that so far no model with Learning by Doing (LBD) includes regional disaggregation and trade.

Missing No Regrets Options

This argument is related to the political, social, and economic barriers to making use of no regrets potentials in developed countries. The possibility to fulfil their commitments by using CDM and/or JI might be more favourable for developed countries than to explore and utilize no regrets opportunities. The potential of no-regrets in developing countries affects the principle of additionality and is therefore a problem in accepting CDM and JI projects (Rentz, 1998).

Implementation

This argument embraces two problem areas: implementation of an institutional framework for instruments at the national and international levels, and compliance with the Kyoto Protocol targets. On the institutional side, there are several impediments to building a strong regime for functional international instruments. These are related to both institutional problems and market imperfections.

The production character of CDM and JI requires a fixed baseline to be defined. The baseline provides an incentive to cheat by setting it unrealistically high so that the efficacy of the instrument decreases because no real reduction takes place. The possibility to cheat stems from the intricacies of fixing the baseline, which usually arise through vague guidelines (political issue) and the general problems of forecasting (technical issue; see Michaelowa, (1995; 1998b). Begg *et al*. (1999) and Parkinson *et al*. (2001) examine the uncertainty associated with baseline construction and propose it be managed through conservative esimates, use of monitored data and verification, and either baseline revision or limited crediting lifetimes. Parson and Fisher-Vanden (1999) argue that the opportunity for self-serving manipulation of project baselines will vary markedly among project types, and suggest a likely bias in any project-based JI system (such as the CDM) towards project types most resistant to baseline manipulation—retrofits and technological carbon management. They also propose a hybrid domestic–international system for project certification to limit the scope for cheating.

In this context, an optimal baseline strategy is required that (first of all) takes into account the high volume of projects that will be needed for the flexible mechanisms to achieve their main objective of an (overall) environmental effectiveness. The balance is likely to be achieved by optimizing baseline stringency and minimizing project complexity (as long as the ability to determine “what would have happened otherwise” is not compromised). The reasoning is that a higher number of effective projects will be more beneficial for the environment (in terms of GHG reductions) than a lower number of individually very effective projects (OECD, 1999a). A related delicate balance should be reached between the requirement for rigorous monitoring and reporting efforts (to ensure environmental effectiveness) and the need to obtain cost-effective and predictable emission benefits via simple procedures that encourage such projects (OECD, 1999b).

The next problem is that each implemented project—especially a large one—affects the baseline in other parts of the economy. Jackson (1995) warns that this might implicate a multilevel system of baselines in the overall economy, sectors, and projects. Clearly, projects have to be monitored. Thus the political problem of creating guidelines for monitoring and the technical issue of registration arise. Furthermore, credible enforcement or penalization against cheating or non-fulfilling parties needs to be established, probably in the form of a special body for ascertainment (Janssen, 1999). A reliable basis of international law for contracting is essential, especially among private actors. Even if all these conditions are fulfilled, the problem of corruption might make the instrument inefficient or flawed outright. With respect to such problems Barrett (1998) raises the question whether the Kyoto Protocol will be implemented at all by any parties if every party believes that other parties do not obey the rules and follow their own commitments.

Turning to the second problem area, the efficient allocation of markets can be distorted by transaction costs associated with searching for partners, and the costs of contracting and negotiations (see Stavins, 1995). Price distortions result when large nations and corporations exercise market power (Hahn, 1984; Hagem and Westskog, 1998), or asymmetric information distribution between partners in JI or CDM projects is exploited by one of them (Hagem, 1996). It is well known that each of these deviations from the ideal world of competitive markets might lead to inefficient allocations. Other factors at work include the initial distribution of property rights, which might also reflect equity considerations.

Corruption and Other Host Internal Problems

Corruption is an important problem in several countries on both sides of the JI and CDM relationships. The negative consequence of corruption is that institutional settings are undermined, especially when hard currency is involved. In many developing countries with weak democratic institutions, politicians have strong incentives to maximize the financial flows and to ignore potential negative consequences. Heller (1995) points out that higher financial inflows from donor countries might result in shrinking domestic environmental budgets, so that no real emissions reduction occurs.

Balance Between Domestic and International Strategies

It is apparent from this section that the relationship between domestic mitigation and the use of international instruments remains an intricate one. Work by Hahn and Stavins (1995) indicates that the link between domestic implementation and international mechanisms may seriously limit the ultimate economic potential of emissions trading. Most economic studies of trading assume that trade occurs whenever there is the potential to lower compliance costs. However, to the extent that some countries implement their domestic strategies through regulatory and tax measures, emissions permits obtained through international transactions may have limited or no value in these countries. Moreover, Hahn and Stavins (1995) point out that domestic legislators may be concerned about the significant financial transfers implied by emissions trading and act to keep funds within their own borders. In another relationship, Montgomery (1997) raises the possibility that domestic legislators may try to impose trade barriers in an effort to limit the competitiveness consequence implied by the loss of capital and jobs that may accompany efforts to limit emissions.

In summary, the literature on where-flexibility reveals abundant opportunities to reduce the costs of emission reductions, but also raises concerns about the implementation. However, concerns as to whether the flexibility mechanisms of the Kyoto Protocol can be implemented because of the possibility that some parties may be corrupt or may cheat are universal concerns. They apply not only to the countries involved in flexibility mechanisms, but also to countries that take on any emissions reduction commitments (although flexibility instruments are particularly sensitive to cheating). Given the various ways proposed to reduce the risks of their misuse, the Kyoto mechanisms offer the double advantage of reducing the costs of climate change mitigation and fostering non-climate objectives as well.

10.4.5 Who Should Pay for the Response? Mitigation by Countries and Sectors: Equity and Cost-effectiveness Considerations

Equity and efficiency considerations in the context of decision making that addresses global climate change are important for various reasons, including ethical concerns, effectiveness, sustainable development, and implementation of UNFCCC itself (Munasinghe, 1998; see also Chapter 1). Principles of justice and fairness[40] are important in themselves, in all types of human interactions, and play a major role in practically all modern international agreements, including the UN Charter; they emphasize the basic equality of all humans (Jepma and Munasinghe, 1998).

Some authors argue that equitable decisions generally carry greater legitimacy and encourage parties with differing interests to co-operate better in carrying out mutually agreed actions. One of the major obstacles to reaching a comprehensive agreement on global warming—setting GHG emission limitation targets for individual countries—involves parties that act as a “veto” because they regard particular arrangements as unfair or unjust. Decisions that are widely accepted as equitable are likely to be implemented with greater willingness than those enforced under conditions of mistrust (Rowlands, 1997). Others find little evidence that fairness matters much. Victor (1999) examines the relationships between fairness and the compliance with international environmental agreements through the lessons learned about implementation and effectiveness of numerous earlier treaties. His conclusion is that equity concerns matter little in the success of negotiating and implementing such agreements. Even for cases in which fairness seems to play some role, willingness to pay had a stronger role. Victor argues that if parties to an agreement take the trouble to deviate from the simplest across-the-board commitments, then many criteria need to be considered in negotiating commitments. Fairness might be one criterion, but is probably not the most important.

In a broader context, equity and fairness are important elements of the social dimension, while efficiency is a crucial factor in the economic dimension of sustainable development. The impetus of sustainable development provides a crucial reason for finding efficient and equitable solutions to the problem of global warming, especially with regard to future generations. The UNFCCC recognizes these two principles in Article 3.1.

Equity principles apply to both procedural and consequential issues (Banuri *et al*., 1996). Procedural issues concern the process of how decisions are made. The two aspects of procedural equity involve the effective participation in decision-making processes and the process itself, which should be the principle of equal treatment before the law. In this context, reference is made to Coase’s model of social cost (1960) in that he assumes a situation of equal bargaining power among participants and equal distribution of the costs of making the bargain with respect to the internalization of externalities. The philosophical notion of procedural equity is the “ideal speech situation” (Habermas, 1981), a situation in which dialogue and decision making are free from inappropriate constraints such as barriers to the acquisition of knowledge or financial resources. Transfer of these concepts to climate change negotiations requires consideration of the influence of scientific information, human resources, institutional capacities, and financial assets on the bargaining, and a redistribution of these among participants to create procedural equity.

Consequential equity deals with the outcome of decision making, and with the distribution of costs and benefits of preventing global warming (including future emission rights) and of coping with the climate change impacts and adaptation. The consequential decisions have implications for burden sharing

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[40] The terms “justice” and “fairness” are often used as synonyms, however, there are debates on the different notions of the terms. Following Albin (1995), justice means distributive justice, in the sense of a general standard for allocating collective benefits and burdens among the members of a community at local, national, or global levels. Principles of justice exist prior to and independently of any phenomenon to be judged. Fairness consists of individual perceptions of what is reasonable under the circumstances, often in reference to how a principle of justice regarded as pertinent should be applied.

Table 10.9: *Equity principles and burden-sharing rules*

Equity principle	Interpretation	General operational rule
Egalitarian	Every individual has an equal right to pollute or to be protected from pollution	Allow or reduce emissions in proportion to population
Sovereignty	All nations have an equal right to pollute or to be protected from pollution; current state of emissions constitutes a status quo (“grand-fathering”)	Proportional reduction of emissions to given or existing emission levels’ or equal percentage of emission reductions
Polluter pays	Welfare losses corresponding to gains by emissions (eventually including historical emissions)	Share abatement costs across countries in proportion to emission levels
Ability to pay	Mitigation costs vary directly with national economic well-being	Equalize abatement costs across nations (costs as proportion of GDP equal for each nation)
Horizontal	All countries with similar features have similar emissions rights and burden-sharing responsibilities	Equalize net welfare change across nations–net cost of abatement as a proportion of GDP
Vertical	Welfare losses vary positively with national economic well-being, welfare gains vary inversely with GDP	Progressively share net welfare change across nations, net gains inversely and net losses positively correlated with per capita GDP
Utilitarian	Achieving the greatest good (happiness) for the greatest number	Maximize net present value of the sum of individuals utility (maximize social welfare).
Compensation	No nation should be made worse off	Compensate net losing nations
Rawls’ maximin	The welfare of the worst-off nations should be maximized	Maximize the net benefit to the poorest nations
Market justice	The market is just	Allocate emissions permits to the highest bidder
Consensus equity	The negotiation process is fair	Seek a political solution to emissions reduction
Convergence	Equalize per capita emissions	Converge to an upper boundary of emissions
Environmental	The environment receives preferential treatment	Maximize environmental values and cut back emissions accordingly

among and within countries (intragenerational and spatial distribution) and between present and future generations (intergenerational and temporal distribution). While actions to mitigate climate change have to be paid for by the present generation, benefits in the sense of avoided losses will affect generations to come. This involves discounting future benefits to a net present value (Portney and Weyant, 1999). However, most of the potentially affected parties are not present to participate in the decision making, so that the current generation has to discuss equity issues within climate change.

In total, four kinds of questions frame the issue of justice in climate change (Shue, 1993), of which the third (procedural equity) provides the basis for a just process in determining the other three kinds of allocations.

1. What is a fair allocation of the costs of preventing the global warming that is still avoidable?
2. What is a fair allocation of the costs of coping with the social consequences of the global warming that will not be avoided?
3. What background allocation of wealth would allow international bargaining about issues like (1) and (2) to be a fair process?
4. What is a fair allocation of emissions of GHGs over the long term and during the transition to the long-term allocation?

To answer these questions scientists have developed typologies for the various distributional equity principles; these are understood to be general concepts of distributive justice and fairness, which often overlap. Associated burden-sharing rules, on the other hand, represent an operational function to generate a specific scheme to reduce GHG emissions or to bear the costs of climate change impacts. *Table 10.9* gives an overview of general equity principles and accompanying operational rules (Thompson and Rayner, 1998).

Major devices to determine the order of equity principles are the following: Rose *et al*. (1998) distinguish between “allocation-based”, “outcome-based”, and “process-based” principles. The first group focuses on the initial allocation of property rights of GHG emissions, such as the egalitarian, sovereignty, polluter pays, and ability-to-pay principles. The second group of principles examines the outcome in terms of welfare changes[41] caused by emissions reduction efforts, such as the horizontal, vertical, compensation, and utilitarian principles. The third category recognizes the libertarian, political consensus, and Rawls' maximin as guiding principles to the process of emission allocation. Shue (1993) divides principles of justice into "fault-based" and "no-fault" principles. The ability-to-pay, for example, is no-fault in the sense that guilt is irrelevant to the assignment of responsibility to pay. The richest should pay the highest rates no matter how they acquired what they own. In contrast, the polluter-pays principle, an economic principle that polluters should bear the cost of abatement without subsidy (Rayner *et al*., 1999), is based upon fault or, alternatively, upon an amoral rationale of causal responsibility, or simply that the assignment of burden creates an incentive to not pollute. Thus, fault need not be a moral issue. Rowlands (1997) differentiates, among other things, according to aspects of historical difference (if any). The classification is based on whether past usage has established present and future rights, be it the same (grandfathering) or be it a correction for injustices from the past (natural debt). Agarwal and Narain (2000) outline the concept of contraction and convergence. This is the entitlement of GHG emissions budgets in terms of future emissions rights. Such a global future emissions budget is based on a global upper limit of atmospheric concentration of CO_2, for instance 450ppmv (contraction). This budget is then distributed as entitlements to emit CO_2 in the future, and all countries will agree to converge on a per-capita emission entitlement (convergence). Level of contraction and timing of convergence are subject to negotiations with respect to the precautionary principle.

The Kyoto Protocol endorses the principle of differentiation among countries (between Annex B and non-Annex B) and within Annex B countries for emissions reduction targets. However, details of the form of JI and the endowment of GHG emissions rights remain to be established. Also, future negotiations to determine national targets after 2012, as well as the question of commitments for developing countries, need to be discussed. Accordingly, several proposals for the differentiation of national GHG reduction targets, as well as multiform modelling exercises to explore the consequences of the different proposals, have been published recently. An overview is given in *Table 10.10*.

The variety of equity principles reflects the diverse expectations of fairness that people use to judge policy processes and the corresponding outcomes. The demand for fairness arises from the existence of communities (social solidarity) and from publicly shared expectations of the conduct of community relations. As communities pursue manifold ways of organizing institutional structures and social relations, there are different perceptions of what is equitable and fair (Rayner *et al*., 1999; Rayner and Malone, 2000). Distinct moral principles generate conflicting debates on how to share the burdens, even though there might be equally legitimate and justified claims. Therefore, it is very difficult to achieve a worldwide consensus on just one justice principle. One way of reaching an accord might be to set up a combination of the diverse equity-based distribution proposals (Müller, 1998). Even if agreement on a particular first principle is reached, the question of how reductions for each country should be generated would remain unresolved because of the different reference bases against which equity cirteria could be applied, such as population, land area, GDP per capita, or emissions per capita. With respect to the spatial distribution of GHG emissions limitation burdens, should the burdens be laid more on the production or on the consumption side of CO_2 emissions and what are the accompanying effects in terms of intragenerational equity (Rose and Stevens, 1998)? In summary, manifold equity principles and different accompanying operational rules exist; these might best be applied as a combination to respect more than just one equity position and thus enhance political feasibility.

However, there is a strong bias towards the principle of efficiency and its underlying utilitarian maxim. Also, it is important to recognize that self-interest plays a crucial role in voting for a specific operation rule, and that self-interests or, alternatively, particular preferences are at the core of economic considerations. Closely related to the concept of preferences is that of willingness-to-pay. Developed countries usually have a much higher willingness-to-pay in terms of solving environmental problems. This is partly because willingness-to-pay depends on the ability to pay. Consequently, it seems reasonable that developed countries bear the primary burden involved in mitigating climate change (Victor, 1999), as endorsed in the Kyoto Protocol. Hence, economics in terms of efficiency is a major aspect when negotiating emissions-limitation commitments.

The problem of distributing emissions-limitation quotas is not solved by economic principles either, because emissions trading yields Pareto efficiency irrespective of the initial distribution of emission permits. Where-flexibility in emissions reduction follows Coase (1960), who addresses the assignment of property rights as an efficient solution to market failure. Under the assumptions of perfect competition, a marketable emissions permit scheme with full trading will be cost-effective no matter how the permits are distributed. It will lead to an equalizing of the marginal costs of emissions reduction across all sources (Nordhaus, 1994a) and generate the same costs no matter which burden-sharing rule is applied. Hence, there is no efficiency–equity trade-off and no obstacle to considering equity issues within climate change while emphasizing cost-

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[41] The comparison and aggregation of welfare in terms of monetary units such as GDP across different countries is a controversial issue. Attempts have been made to incorporate equity considerations through weighting the welfare changes, giving attention to the unequal distribution of wealth among developed and developing countries (Tol *et al*., 1999).

Table 10.10: *Selected studies of applied equity principles and burden-sharing rules*

Reference	**Subject of investigation**	**Geographical mapping**	**Results**			
			Numerical results*			
Torvanger and Godal (1999)	Emission limitations that could occur if burdens were to follow the	Countries in Baltic Sea Region	Sov.	Egal.	Abil.	
			all			
	• Sovereignty principle	Denmark	–6	18	–14	
	• Egalitarian principle (to fulfil the Kyoto Protocol)	Estonia	–6	–37	–4	
		Finland	–6	27	–15	
	• Ability-to-pay principle (assuming no increase in emissions)	Germany	–6	8	–12	
		Iceland	–6	45	–13	
		Latvia	–6	23	–4	
		Lithuania	–6	19	–3	
		Norway	–6	29	–13	
		Poland	–6	15	–1	
		Russia	–6	112	–14	
		Sweden	–6	–20	–4	
			* changes compared to 1990 levels, in per cent			
Rose *et al*. (1998)		Global, 9 Regions	Sov.	Egal.	Hor.	Vert.
	• Sovereignty	USA	8.2	67.7	9.5	17.3
	• Egalitarian	Can, W. Europe	5.6	29.8	7.0	3.3
	• Horizontal	Other OECD	1.5	12.5	3.8	8.2
	• Vertical	EEFSU	6.2	55.9	4.1	1.1
		China	3.9	-25.4	1.2	0.0
		Middle East	1.0	0.3	1.3	0.6
		Africa	0.8	-36.3	0.8	0.0
		Latin America	1.3	-10.6	1.3	0.1
		Southeast Asia	2.1	-63.3	1.6	0.0
	EEFSU: Eastern Europe and Former Soviet Union		* net cost impacts in the year 2005, in billions of 1990 US$			
OECD/IEA (1994)	Emission limitations following 10% reduction in world emissions according to	Global, 10 Regions		Egal.	Hor.	Vert.
		North America		11	2.5	12
		West/North Europe		7	2	12
	• Egalitarian	Pacific OECD		21	3	52
	• Horizontal	Central/E. Europe		25	39	6
	• Vertical	Former SU		11	8	4
		East Asia		8	14	6
		China		3	23	2
		Middle East		23	24	13
		Latin America		7	12	5
		Africa		5	24	3
			* in per cent			

(continued)

Table 10.10: *continued*

Reference	Subject of investigation	Geographical mapping	Main features
Elzen *et al*. (1999, 2000) FAIR model (Framework to Assess International Regimes for burden sharing)	• the Brazilian proposal (revised and original approach), as application of polluter-pays principle • Brazilian methodology for estimating historical emissions	Analysis extended to global scale	• only allocation-based criteria • accounting for historical emissions and/or a per-capita approach favour developing countries • inclusion of all GHG and land use emissions favours developed countries
	• Triptych approach Phylipsen *et al*. (1998) Blok *et al*. (1997) Sector oriented		• energy-related CO_2 emissions may still increase because of high growth in non-Annex I emissions, especially in industrial sector • energy efficiency plays a major role in emissions reduction if combined with global diffusion of technology
Byrne *et al*. (1998)	Proposal for egalitarian principle on the basis of 1989 population	140 countries Four income groups	• achieving economic parity in 2050 • increase in CO_2 emissions for low-income countries • reduction in CO_2 emission for upper-income countries
Ringuis *et al*. (1998)	Horizontal: equal weight, CO_2/capita, CO_2/unit GDP, GDP/capita, GDP, CO_2	OECD	• none of the rules in which it is possible to allocate costs among countries and into economic and social drivers equalizes costs across the OECD
Rowlands (1997)	Historical (reactive and proactive) Equality Efficiency	OECD	• twin-track strategy: short term flat-rate approach, long-term differentiated approach

Note: EEFSU= Eastern Europe and Former Soviet Union

effectiveness. Equity rules play an important role when determining the initial distribution of emissions allowances, or the compensation schemes, as cost-effectiveness might result in a disproportionately high level of burden to certain groups of countries. Attempts can be made to provide resource transfers to compensate for the disadvantaged (Biermann, 1997). Usually, it is assumed that mitigation costs are relatively higher in developed countries. Thus, trading reduces the costs to developed countries and provide a transfer to developing countries. Yet, the magnitude of side payments needs to be considered when evaluating alternative burden-sharing rules, because they often generate rather high transaction and/or administrative costs (Burniaux, 1999). If, however, use of the flexibility mechanisms is restricted and equalization of marginal abatement costs throughout the countries cannot be fulfilled, the choice of burden-sharing rule matters with respect to the aggregate abatement costs. Furthermore, emissions trading is usually perceived to take place in a perfect market with parties having equal opportunities of involvement. Agarwal and Narain (1991) see an advantage for developed nations who have stronger market capacities.

Montgomery (1997) points out that it is not only international negotiators who must consider equity, but also domestic legislators. In an attempt to limit the competitiveness consequences implied by the loss of capital and jobs that may accompany efforts to limit domestic emissions, legislators may act to impose trade barriers. This is another aspect of the need to link international equity and negotiations to the fairness concerns in domestic implementations.

This section shows that equity, opportunities for cost-effectiveness, and flexibility are among the main criteria that a burden sharing rule should satisfy. While it is clear that Pareto optimality is a broadly accepted efficiency principle, there is no agreement on a best equity principle. Therefore theories of justice do not generate one best solution for the international allocation of emissions permits. It appears more important to emphasize negotiating principles that are widely accepted, regarded as equitable, and politically feasible. Beckerman and Pasek (1995), for instance, propose to minimize the proportionate loss of welfare in any voluntary agreement for public goods and lay a smaller burden on the poorest participants.

Much of the debate about equity in climate change mitigation deals with social, economic, and political issues, including international economic development and the unequal distribution of wealth within and among countries. Views diverge widely. Is climate change an opportunity to solve the large problems of sustainable development and global distribution of wealth? Or would broadening the scope for the anyway complex and controversial issue of climate change run the risk of neither solving the climate problem nor improving prospects for sustainable development. Helm (1999) presents an analysis of fair sharing of GHG limitation burdens by separating the climate issue from the dispute about the global welfare distribution. In contrast, Rayner and Malone (2000) pursue a holistic approach to equity and address climate change as an arena in which to debate a wide variety of economic and political issues. In this context, equity is perceived as a basis for generating social capital, which is necessary, together with economic, natural, and intellectual capital, for sustainability.

10.4.6 Towards what Objective Should the Response Be Targetted? High versus Low Stabilization Levels–Insights on Mitigation

In a rational world, the ultimate level of climate and thus GHG concentration stabilization would emerge from a political process in which the global community would weigh mitigation costs and the averted damages associated with different levels of stabilization. Also weighed would be the risks of triggering systemic changes in large geophysical systems, like ocean circulation, or other irreversible impacts. In reality, the political process will inevitably be influenced by the distribution of positive and negative effects of climate change, as well as by the costs of mitigation among countries, largely determined by how risks, costs, environmental values, and development aspirations are weighed in different regions and cultures. This process will be strongly influenced by new scientific and technical knowledge and by experience gained in making and implementing policy. The climate change literature contains a diversity of arguments as to why either a low level or a relatively high level of stabilization is desirable (IPCC, 2001b).

Given the large uncertainties that characterize each component of the climate change problem, it is impossible to establish a globally acceptable level of stabilized GHG concentrations today. Studies discussed in this section and summarized in *Table 10.11* support the obvious expectations that lower stabilization targets involve exponentially higher mitigation costs and relatively more ambitious near-term emissions reductions, but, as reported by WGII (IPCC, 2001b), lower targets induce significantly smaller biological and geophysical impacts and thus induce smaller damages and adaptation costs.

10.4.7 Emerging Conclusions with Respect to Policy-relevant Scientific Questions

Looking at the dilemmas covered in previous sections, the following conclusions emerge:

- a carefully crafted portfolio of mitigation, adaptation, and learning activities appears to be appropriate over the next few decades to hedge against the risk of intolerable magnitudes and/or rates of climate change (impact side) and against the need to undertake painfully drastic emission reductions if the resolution of uncertainties reveals that climate change and its impacts might imply high risks;
- the nature of the climate change problem requires that mitigation action at any level needs to start in the near term, as well as the development of appropriate adaptation strategies;
- emission reduction is an important form of mitigation, but the mitigation portfolio includes a broad range of other activities, including investments to develop low-cost non-carbon energy, and to improve energy efficiency and carbon management technologies to make future CO_2 mitigation inexpensive;
- timing and composition of mitigation measures (investment in technological development or immediate emission reductions) is highly controversial because of the technological features of energy systems, and the range of uncertainties involved with, for example, their impacts of climate change;
- international flexibility instruments help reduce the costs of emission reductions, but they raise a series of implementation and verification issues that need to be balanced against the cost savings;
- while there is a broad consensus on Pareto optimality as an efficiency principle, there is no agreement on the best equity principle for burden sharing. Efficiency and equity are important concerns in negotiating emissions limitation schemes, and they are not mutually exclusive. Therefore, equity will play an important role in determining the distribution of emissions allowances and/or within compensation schemes that follow emissions trading resulting in a disproportionately high level of burden to certain countries. Finally, it is more important to rely on politically feasible burden-sharing rules than to select one specific equity principle.

Finally, a series of potential large-scale geophysical transformations that might exert a major influence on the desired level of stabilization have been identified and examined more closely in recent years. These imply thresholds that humanity might decide not to cross because the potential impacts or even the associated risks are considered to be unacceptably high. Little is know about these thresholds today. Most recent results and

Table 10.11: *Selected studies on global mitigation costs for different stabilization targets*

Study	Scenarios & dimensions	450ppmv	550ppmv	650ppmv	750ppmv	850ppmv	Notes
Nordhaus and	billion 1990 US$						discounted (d) back
Boyer (1999)	net impacts on global welfare		335.00				to 1950
RICE-98	difference from base (=0)						IAM
	mitigation		459.00				
	reduction in cl.damage		794.00				
Valverde and	in billion 1985 US$						1985-2100, 5 year time
Webster (1999)	500a global emissions path		(500ppmv)				steps
MIT-EPPA 1.6	all nations equal % abatement						d= 5%
	OECD: no trade		272.50				
	OECD: trade:		272.40				
	Non-OECD: no trade:		216.30				
	Non-OECD: trade		216.20				
	Global: no trade:		488.90				
	Global trade		488.60				
Manne and Richels	billion of 1990 US$						
(1999b)	Kyoto followed by arbitrary reduc.		2400.00				consumption loss
MERGE 3.0	Kyoto followed by least-cost		900.00				through 2100
	least cost		650.00				d=5% to 1990
Tol (1999c), FUND	percentage of world income, median		2.1%				average annual income loss
							9 regions, 5 sectors
							in 2100
Ha-Duong et al.	percentage of 1990 GWP						d=3%
(1997)	inertia of 50 years	1.1%					average annual costs
DIAM							period 2000–21000
Lecocq et al. (1998)	percentage						average annual costs
STARTS	abatement costs as consumption loss						period 2000-2100
	compared to BAU in						differential inertia in
	A: flexible sector		1,5%				sectors
	B: rigid sector		0.4%				

(continued)

Table 10.11: *continued*

Study	Scenarios & dimensions	450ppmv	550ppmv	650ppmv	750ppmv	850ppmv	Notes
Yohe and Wallace (1996) **Connecticut**	percent of GWP as costs in 1990, no benefit side one percentage point is ~210 billion US$		16.40 to 16.69	5.94 to 7.09	2.84 to 4.24	1.59 to 3.05	d, expected present value 7 scenarios
Dowlatabadi (1998) ICAM-3	percentage of GDP as costs mitigation costs within 9 scenarios with different technical change in energy sector		0.05 to 0.48				period: 2000–20025 sequential learning framework mitigation costs for the USA and Canada only
Richels a. Edmonds (1995) Global 2100 & ERB	percentage of GWP as costs	(400)	(500)				d=5% stabilization in 2100 Global 2100 Manne/Richels ERB: Edmonds-Reilly-Barns (1992)
	Sc:500a: follow BAU through 2010		Gl 2100: 0.6 %; ERB: 0.7%				
	Sc: 500b: between 500a & stab.		Gl 2100: 0.9 %; ERB: 0.95%				
	Sc: Emission stabilization at		Gl 2100: 1.15 %; ERB: 1.1%				
	1990 level	Gl: 0.9%; ERB:1.1%	Gl:0.6%; ERB: 0.7%				
Plambeck, Hope (1996) PAGE95	in trillion US$						d= 5 %, 1990-2200 further scenarios not listed here, e.g.: non-linear etc.
	BAU + 100 GtC:	2.50					
	BAU:	2.20					
Yohe and Jacobsen (1999) Connecticut	trillion 1990 US$ annual control costs of 7 sc						d=3 % through 2100 (Ramsey) cost study in terms of deadweight loss, no opt A: alt. sink specifications B: alt. emissions targets for 2010
	Minimum cost: Sc3 to Sc7	A: 10.13 to 44.40	A: 2.11 to 16.12	A: 0.36 to 7.24			
	Cost with Kyoto: Sc3 to Sc7	A: 10.47 to 47.04	A: 2.12 to 16.19	A: 0.40 to 7.26			
	Minimum cost minus 10 % emis.	B: 10.13 to 44.40	B: 2.11 to 16.12	B: 0.36 to 7.24			
	Cost with Kyoto minus 10 %	B: 10.40 to 46.77	B: 2.13 to 16.16	B: 0.42 to 7.28			
Manne (1995) MERGE	trillion 1990 US$	(415 ppmv)					d= 5 % to 1990
	global damage	1.90					
	benefits of stab.as reduced dam.	2.50					
	costs of stab.	18.50					

(continued)

Table 10.11: *continued*

Study	Scenarios & dimensions	450ppmv	550ppmv	650ppmv	750ppmv	850ppmv	Notes
Manne and Richels	trillion 1990 US$						
(1997)	WGI: w/o where flex.	14.20	9.00	5.00	3.00		d=5% to 1990
MERGE 3.0	WGI: with where flex	7.00	4.00	2.00	1.2		1990-2100
	WRE: w/o where flex	5.50	2.00	1.00	1.00		non-market and
	WRE: with where flex	3.50	1.00	0.6	0.50		market damages
	least cost: with where flex		0.60				
	WGI: Annex-1-trade		5.90				
	10% cut in 2010: A-1-trade		2.30				
	WRE: A-1-trade		0.90				
Tol (1999d),	trillion net present costs in US$						
FUND 1.6	WGI: no trade	32.50	17.5	10.50			5% through 2050
	WGI: trade	17.50	8.0	4.00			damage per year
	WRE: no trade	34.00	16.0	10.00			in billion US$: 216
	WRE: trade	13.00	4.0	2.00			
Tol (1999a)	in trillion US$		below 550				
FUND 1.6	Minimum Cost		2.4				d= 5% per year to 1990
	Min. Cost meeting Kyoto, trade		3.1				consumption losses p.a.
	Min. Cost meeting Kyoto		3.7				period 1990-2200
	2 % reduction, intern. trade		4.0				
	meeting Kyoto, trade		4.4				
	meeting Kyoto, no trade		14.6				

the implications of the possibility of such thresholds are summarized in Chapter 19 of WGII (IPCC, 2001b). Nevertheless, currently estimated "danger zones" are in the domain of high stabilization levels for most threshold events.

Considering the special combination of features of the climate problem listed at the beginning of this chapter, it is obvious that no "once forever" solution exists. Making long-term commitments in any area where retraction is possible is problematic. Making decisions that entail long-term and possibly irreversible consequences due to long delays, inertia and similar system properties is even more difficult, especially under severe uncertainties. Therefore, as emphasized in this chapter, the most promising approach to climate policy is sequential decision-making. This process involves a regular reassessment of the long-term climate risks (net damages from a given magnitude of climate change) and their management objectives (climate or GHG concentration stabilization) in the light of newly available information. Short-term strategies are then crafted so that both GHG emissions and the underlying socioeconomic processes (resource use, technologies) evolve in a direction which makes future course corrections in any direction the least expensive. The current structure of the international climate regime is formulated in this vein: the UNFCCC provides some, albeit vague, guidelines for long term stabilization objectives while short-term goals are settled in and implemented under protocols for each budget period.

The analytical tools to support the above decision-making processes need to handle this double feature. They should provide policymakers with guidance to set long-term targets and to formulate short-term policies and measures. Some models take a long-term view to explore deep future impacts of climate change, but this must not be interpreted as suggesting optimal strategies for the next 50-100-200 years. Other models explore what are the most promising near-term policies and how to implement them. Similarly, many studies and models reviewed in this chapter consider the world as a whole or broken down into a few regions, at best. Others take a more detailed look at subnational and regional aspects. They shed light on the smaller scale implications of climate change and its management strategies, often in the context of other social concerns characterizing the country or region. Our assessment has found a healthy diversity of DAFs along both the long-term-short term and the global-local axes. Nevertheless, the analytical capacity and thus quotable results are still badly missing in most developing countries. This is probably the most severe problem to be solved by the time the world community will prepare its next climate change assessment report.

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