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Setting the Stage: Climate Change and Sustainable Development

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EXECUTIVE SUMMARY

This chapter places climate change mitigation, mitigation policy, and the contents of the rest of the report in the broader context of development, equity, and sustainability. This context reflects the explicit conditions and principles laid down by the UN Framework Convention on Climate Change (UNFCCC) on the pursuit of the ultimate objective of stabilizing greenhouse gas concentrations. The UNFCCC imposes three conditions on the goal of stabilization, namely, that it should take place within a time-frame sufficient to "allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (Art. 2). It also specifies several principles to guide this process: equity, common but differentiated responsibilities, precaution, cost-effective measures, right to sustainable development, and support for an open international economic system (Art. 3).

Previous IPCC assessment reports sought to facilitate this pursuit by comprehensively describing, cataloguing and comparing technologies and policy instruments that could be used to achieve mitigation of greenhouse gas emissions in a cost-effective and efficient manner. The present assessment advances this process by including recent analyses of climate change that place policy evaluations in the context of sustainable development. This expansion of scope is consistent both with the evolution of the literature on climate change and importance accorded by the UNFCCC to sustainable development - including the recognition that "Parties have a right to, and should promote sustainable development" (Art. 3.4). It therefore goes some way towards filling the gaps in earlier assessments.

Climate Change involves complex interactions between climatic, environmental, economic, political, institutional, social, and technological processes. It cannot be addressed or comprehended in isolation from broader societal goals (such as sustainable development), or other existing or probable future sources of stress. In keeping with this complexity, a multiplicity of approaches have emerged to analyze climate change and related challenges. Many of these incorporate concerns about development, equity, and sustainability (albeit partially and gradually) into their framework and recommendations. Each approach emphasizes certain elements of the problem, and focuses on certain classes of responses, including for example, optimal policy design, building capacity for designing and implementing policies, strengthening synergies between climate change mitigation and/or adaptation and other societal goals, and policies to enhance societal learning. These approaches are therefore complementary rather than mutually exclusive.

This chapter brings together three broad classes of analysis, which differ not so much in terms of their ultimate goals as in their points of departure and preferred analytical tools. The three approaches start with concerns, respectively, about efficiency and cost-effectiveness, equity and sustainable development, and global sustainability and societal learning. The difference between the three approaches we have selected lies in their starting point, not in their ultimate goals. Regardless of the starting point of the analysis, many studies try in their own way to incorporate other concerns. For example, many analyses that approach climate change mitigation from a cost-effectiveness perspective try to bring in considerations of equity and sustainability through their treatment of costs, benefits, and welfare. Similarly, the class of studies motivated strongly by considerations of inter-country equity tend to argue that equity is needed to ensure that developing countries can pursue their internal goals of sustainable development–a concept that includes the implicit components of sustainability and efficiency. Likewise, analysts focused on concerns of global sustainability have been compelled by their own logic to make a case for global efficiency–often modelled as the decoupling of production from material flows–and social equity. In other words, each of the three perspectives has led writers to search for ways to incorporate concerns that lie beyond their initial starting point. All three classes of analyses look at the relationship of climate change mitigation with all three goals–development, equity, and sustainability–albeit in different and often highly complementary ways. Nevertheless, they frame the issues differently, focus on different sets of causal relationships, use different tools of analysis, and often come to somewhat different conclusions.

There is no presumption that any particular perspective for analysis is most appropriate at any level. Moreover, the three perspectives are viewed here as being highly synergistic. The important changes have been primarily in the types of questions being asked and the kinds of information being sought. In practice, the literature has expanded to add new issues and new tools, subsuming rather than discarding the analyses included in the other ones. The range and scope of climate policy analyses can be understood as a gradual broadening of the types and extent of uncertainties that analysts have been willing and able to address.

The first perspective on climate policy considered is Cost-effectiveness. It represents a perspective that is well represented in conventional climate policy analysis and in the First through Third Assessments. These analyses have generally been driven directly or indirectly by the question of what the most cost-effective amount of mitigation for the global economy is, starting from a particular baseline greenhouse gas (GHG) emissions scenario, reflecting a specific set of socioeconomic scenarios. Within this framework, important issues include measuring the performance of various technologies and the removal of barriers (such as existing subsidies) to the implementation of those candidate policies most likely to contribute to emissions reductions. In a sense, the focus of analysis here has been on identifying an efficient pathway through the interactions of mitigation policies and economic development, conditioned by considerations of equity and sustainability, but not primarily guided by them. At this level, policy analysis has almost always taken the existing institutions and tastes of individuals as given; assumptions that might be valid for a decade or two, but may become more questionable over many decades.

The impetus for the expansion in the scope of the climate policy analysis and discourse to include Equity considerations was to include considerations not simply of the impacts of climate change and mitigation policies on global welfare as a whole, but also of the effects of climate change and mitigation policies on existing inequalities among and within nations. The literature on equity and climate change has advanced considerably over the last two decades, but there is no consensus on what constitutes fairness. Once equity issues were introduced into the assessment agenda, though, they became important components in defining the search for efficient emissions mitigation pathways. The considerable literature that indicated how environmental policies could be hampered or even blocked by those who considered them unfair became relevant. In the light of these results, it became clear how and why any widespread perception that a mitigation strategy is unfair would likely engender opposition to that strategy, perhaps to the extent of rendering it non-optimal. Some cost-effectiveness analyses had, in fact, laid the groundwork for applying this literature by demonstrating the sensitivity of some equity measures to policy design, national perspective, and regional context. Indeed, cost-effectiveness analyses had even highlighted similar sensitivities for other measures of development and sustainability.

As mentioned, the analyses that start from equity concerns have by and large focused on the needs of developing countries, and, in particular, on the commitment expressed in Article 3.4 of the UNFCCC to the pursuit of sustainable development. Assessing the climate challenge from a sustainable development perspective immediately reveals that countries differ in ways that have dramatic implications for scenario baselines and the range of mitigation options that can be considered. The climate policies that are feasible, and or desirable, in a particular country depend importantly on its available resources and institutions, and on its overall objectives including climate change as but one component. Moreover, although OECD centered models may give helpful first order insights into the efficacy of global scale policy interventions, their underlying assumptions may make them less useful when the heterogeneity of nations is fully incorporated. Recognizing this heterogeneity may lead to a different range of policy options than has been considered likely thus far and may ultimately feed back into policy design for Annex I. Recognizing heterogeneity among countries reveals, in short, differences in the capacities of different sectors that may also enhance appreciation of what can be done by non-state actors as well as governments to build their ability to mitigate.

While sustainability has been incorporated in the analyses in a number of ways, a class of studies takes the issue of Global Sustainability as the point of departure. One popular method for identifying constraints and opportunities within this perspective is to identify future sustainable states and then examine possible transition paths to those states for feasibility and desirability. In the case of developing countries this leads to a number of possible strategies that can depart significantly from what the developed countries pursued in the past.

The chapter closes with a discussion of preliminary attempts to integrate the information and insights that result from studies done from the three perspectives. Within this report the concept of "co-benefits" is used to capture dimensions of the response to mitigation policies from the equity and sustainability perspectives in a way that could be used to modify the cost projections produced by those working form the cost-effectiveness perspective although ancillary benefit has been more widely used in the literature. The concept of "mitigative capacity" is also introduced as a possible way to integrate results derived from the application of the three perspectives in the future.

1.1 Introduction

This chapter puts climate change mitigation and climate change mitigation policy in the broader context of development, equity, and sustainability. The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) "is to achieve … stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (Article 2). The UNFCCC goes on to specify principles that should guide this process: equity, common but differentiated responsibilities, precaution, cost-effectiveness, the right to sustainable development, and the avoidance of arbitrary restriction on international trade (Article 3). Previous Intergovernmental Panel on Climate Change (IPCC) assessment reports sought to lay the groundwork for policymakers pursuing the UNFCCC goals by comprehensively describing, cataloguing, and comparing technologies and policy instruments that could be used to achieve the mitigation of GHG emissions.

The attention accorded in the UNFCCC to sustainable development–including the recognition that "Parties have a right to, and should promote sustainable development" (Article 3.4)–has not, however, been matched by its treatment in previous IPCC assessment reports. As a result, the present assessment seeks to address this mismatch by placing policy evaluations in the broader context of development, equity, and sustainability as outlined in the Convention. The rising stature of development, equity, and sustainability in the discussion of mitigation is, indeed, entirely consistent with the overall evolution of the scope of the literature on climate change.

In fact, the analysis of climate change policies has evolved significantly between the preparation of the First Assessment Report (FAR; IPCC, 1991), the Second Assessment Report (SAR; IPCC, 1996), and Third Assessment Report (TAR) of the IPCC. In the late 1980s, for example, the focus of policy analysis was almost exclusively on climate change mitigation through emissions reduction. GHG emissions were modelled almost exclusively in terms of carbon dioxide (CO_2) from energy use (Nordhaus and Yohe, 1983; Edmonds and Reilly, 1985); and emissions reductions were to be achieved primarily by increasing the prices of fossil fuels. Hence, it is hardly surprising that, with a few exceptions (e.g., Bradley and Williams, 1989; Parikh *et al*., 1991), carbon taxes were overwhelmingly the most commonly analyzed policy instrument. FAR (IPCC, 1991) documents the possible ramifications of a wide range of policy instruments, but it reports that carbon taxes are again the most fully analyzed in the literature. This report, by way of contrast, demonstrates a significant enhancement in the capacity of policy analysts to consider the sources and sinks of multiple gases as well as a broader array of policy instruments to curtailing the emission of these gases into the atmosphere. Also, little consideration was given in FAR to policies designed to enhance adaptation to climate change impacts. In TAR, though, adaptation has become a major focus of the Working Group II (WGII) report (IPCC, 2001). At the beginning of the 1990s, assessments of the capabilities of countries to achieve emissions reductions were almost exclusively based on estimates of their fossil fuel consumption. With a few exceptions (e.g., Grubb, 1991; Rayner, 1993) no explicit consideration was given to social, cultural, political, institutional, or decision-making constraints on the capacity of governments to implement climate change policies.

Consistent with the state of the policy literature on climate change, FAR (IPCC, 1991) also made no attempt to address issues of equity. Prior to the publication of *Global Warming in an Unequal World* (Agarwal and Narain, 1991a), consideration of the fairness of climate change policies (both among and within countries) received little attention from analysts and policymakers (for exceptions see Grubb, 1989; Kasperson and Dow, 1991; Parikh *et al*., 1991). The IPCC Second Assessment Report WGIII (IPCC WG III, 1996) did, however, mention the need to extend the focus of analysis and assessment into areas that included issues not only of equity and fairness, but also of development and sustainability. Some of the studies available then did note the distributional effects of alternative policy designs and targets; and some did trace other effects into the domains of development and sustainability. The point here is not that earlier work ignored these broader issues, but that this report begins the process of making them more central in the assessment of the existing policy analyses. This report begins the task of integrating technology and policy characterizations into alternative development scenarios and policy decision-frameworks that are broadly conceived. In the same spirit, this chapter seeks to locate the work of WGIII in a broader context of development, equity, and sustainability. In the process, we draw on several themes (elaborated in subsequent chapters) to identify opportunities to enhance the capacity of regions, countries, and communities to mitigate GHG emissions while simultaneously pursuing their sustainable development goals. Neither the greenhouse gas mitigation nor the sustainable development initiative, however, eliminates the need to conduct efficiency-based assessments of the opportunity costs of mitigation and/or the enhancement of the capacity to mitigate. Instead, climate change and sustainable development both simply expand the number of objectives against which these costs need to be measured.

The expansion of IPCC's scope in this WGIII report complements that of WGII (IPCC, 2001), which addresses the impacts of continued atmospheric accumulation of GHGs and the adaptive capacity of countries to adjust to the consequences of that accumulation. The analogous concept of mitigative capacity (Yohe, in press) is offered in Section 1.5 as one tool with which policymakers and researchers alike might integrate insights drawn from the domains of cost-effectiveness, equity, and sustainability into their understanding of mitigation. Drawing attention to concepts like mitigative capacity also allows the reader to approach the complexity of mitigation within a framework that mirrors the emphasis placed on adaptive capacity by the TAR WGII Report.

The expansion of the range and scope of IPCC policy analysis, just described, can be understood as a gradual broadening of the types and extent of uncertainties that analysts have been willing and able to address. A graphic representation of this expansion of interest and capability (*Figure 1.1*) shows that the policy sciences have made significant advances since IPCC FAR. This figure simply depicts different perspectives that have been employed to examine climate policy issues and the stage at which they were incorporated into the IPCC process. Progression through the IPCC assessments displayed in *Figure 1.1* represents expansions in the scope of climate policy analyses since 1980. There is no presumption that any particular framework for analysis is most appropriate at any level. The important changes are primarily in the types of questions being asked and the kinds of information being sought. In practice, the literature has expanded to add new issues and has subsumed rather than discarded the analyses of the initial issues. With each assessment, IPCC has added to the necessary tool set without obviating the need for the tools developed in the earlier assessments.

The first concern of policy analysis to be included in IPCC assessments is labelled "Cost-effectiveness" in *Figure 1.1*. It represents the field of conventional climate policy analysis that is well represented in the First through to the Third Assessments. These analyses are generally driven directly or indirectly by the question of what is the most cost-effective amount of mitigation for the global economy starting from a particular baseline GHG emissions scenario, and reflecting a specific set of socioeconomic scenarios. Within this framework, important issues include measuring the performance of various technologies and the removal of barriers (such as existing subsidies) to the implementation of the candidate policies

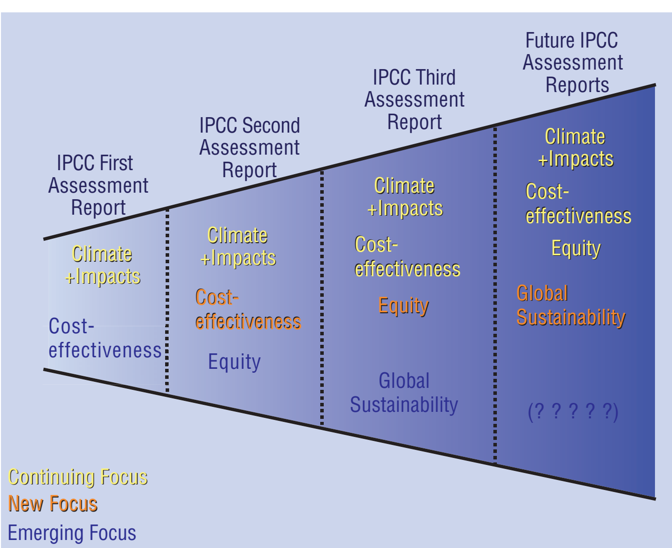

***Figure 1.1**: Evolution of the IPCC assessment process.*

most likely to contribute to emissions reductions. In a sense, the focus of such analysis is to identify an efficient pathway through the interactions of mitigation policies and economic development, in some cases conditioned by considerations of equity and sustainability, but not primarily guided by them. At this level, IPCC policy analysis has almost always taken the existing institutions and tastes of individuals as given; such assumptions might be valid for a decade or two, but may become more questionable over many decades.[1]

By introducing the issue of equity, SAR (IPCC, 1996) broadened the IPCC policy discourse; a process reflected by "Equity" in *Figure 1.1*. The impetus for this expansion in the scope of the discourse was to include considerations not simply of the impacts of climate change and mitigation policies on global welfare as a whole, but also of the effects of climate change and mitigation policies on existing inequalities among and within nations. The literature on equity and climate change has advanced considerably since SAR, but there is no consensus on what constitutes fairness. Once equity issues were introduced into the IPCC assessment agenda, though, they became important components in defining the search for efficient emissions mitigation pathways. The considerable literature that indicates how environmental policies could be hampered or even blocked by those who considered them unfair became relevant (National Academy of Engineering, 1986; Rayner and Cantor, 1987; Grubb, 1989; Weiss, 1989; Kasperson and Dow, 1991). In light of these results, it became clear how and why any widespread perception that a mitigation strategy is unfair would likely engender opposition to that strategy, perhaps to the extent of rendering it non-optimal (or even infeasible). Some cost-effectiveness analyses had, in fact, laid the groundwork for applying this literature by demonstrating the sensitivity of some equity measures to policy design, national perspective, and regional context. Indeed, cost-effectiveness analyses had even highlighted similar sensitivities for other measures of development and sustainability.

Throughout this evolution, though, the historical model of societies that industrialized in the nineteenth and twentieth centuries served as the central notion of what constitutes development in both the cost-effectiveness and equity perspectives. According to some analysts (e.g., Simon and Kahn, 1984; Beckerman, 1996) this path represents the best model for global prosperity. However, a growing parallel literature recognizes the importance of diverse development pathways in achieving an environmentally and socioeconomically sustainable world (see Section 1.4). This insight can serve as the basis of a third analytical perspective–a perspective represented in *Figure 1.1* by "Global Sustainability". As yet, however, analyses of such alternative development pathways remain largely unrealized within the framework of IPCC. Still, the first steps in this direction can be detected throughout this volume.

[1] Recent work in the theory of public choice (e.g., Michaelowa and Dutschke, 1998) suggests that a more dynamic view of institutions can be incorporated into this style of analysis.

The above description of three complementary perspectives on climate change mitigation and the broad societal goals of development, equity, and sustainability bears elaboration. The rest of this chapter can be seen as a triptych, in which each section presents a particular perspective on climate change mitigation–motivated respectively by considerations of cost-effectiveness, equity, and sustainability. However, we also describe how each of the perspectives has attempted to address and incorporate concerns that lie beyond their initial starting points. For example, Section 1.2 details the Cost-effectiveness perspective; however, its two concluding sections, (1.2.5 and 1.2.6) describe how this approach has addressed concerns of equity and sustainability. Similarly, Section 1.3 is entitled "Equity and Sustainable Development" in recognition of the fact that writers examining the issue of climate change from a vantage point of global equity have generally sought to explore how developing countries could pursue their sustainable development goals. In the penultimate sub-section (1.3.4) of this section, we examine the concept of sustainable development and describe its relationship to cost-effectiveness, efficiency, and sustainability. Finally, the theme of Section 1.4 is Global sustainability; and its two main sub-sections (1.4.2 and 1.4.3) discuss issues of resource efficiency (de-coupling growth from resource flows), and values and norms that include issues of equity.

In other words, instead of forcing the literature that describes the relationship between climate change mitigation and development, equity, and sustainability into a single framework, we have tried to bring out both the commonalities and differences between alternative approaches and analytical frameworks. All three classes of analyses look at the relationship of climate change mitigation with all three goals–development, equity, and sustainability–albeit in different and often highly complementary ways. Nevertheless, they frame the issues differently, focus on different sets of causal relationships, use different tools of analysis, and often come to somewhat different conclusions. Accordingly, they are likely to be useful to decision makers in different ways.

Assessing the climate challenge with a sustainable development perspective immediately reveals that countries differ in ways that have dramatic implications for baselines and the range of mitigation options that can be considered. Moreover, although models centred on Organization of Economic Co-operation and Development (OECD) countries may give helpful first-order insights into the efficacy of global policy interventions, the underlying assumptions may make such models less useful when the heterogeneity of nations is incorporated fully. Recognition of this heterogeneity may lead to a different range of policy options than considered likely thus far, and may ultimately feed back into policy design for Annex I countries. Recognizing heterogeneity among countries reveals, in short, differences in the capacities of different sectors, which may also enhance appreciation of what can be done by non-state actors as well as governments to build their mitigative capacity.

The expansion of analytic perspectives also represents the increasing complexity of issues selected for analytic focus. On the left-hand side of *Figure 1.1*, complexity refers primarily to the analytical challenges presented by individual technologies (such as fuel cells or photovoltaics) or specific policy instruments (such as carbon taxes or tradable emissions permits). Moving from left to right across the figure, such complexities become compounded, first by interactions among technologies and policy instruments, then among mitigation and adaptation issues, and, finally among climate change issues narrowly defined and a wide range of environmental and socioeconomic issues. Finally, linkages and interactions with policy objectives for the development of the global economy come into the picture.

A major part of the complexity that must be dealt with in formulating climate policies is the uncertainties about how the world and the climate system will evolve without new policies, about what policies will be implemented now and in the future, and about the efficacy of those policies. The economist Frank Knight (1921) introduced a fundamental distinction between "risk" and "uncertainty",[2] whereby risk refers to cases for which the probable outcomes are predicted through well-established theories and methods, and with reliable data (e.g., the radiative forcing of a tonne of CO_2 or the efficiency of a gas turbine); and uncertainty to situations in which theories and methods are widely accepted, but the appropriate data are not available or are fragmentary, and probabilities and outcomes can be assessed subjectively by relevant experts. In this situation, formal decision-analytic tools can be quite useful, but only if carefully and systematically applied (Savage, 1954; Raiffa, 1968; Howard, 1980, 1988: Howard and Matheson, 1984). There is, however, a third state in the climate context, which may be called decision making under deep uncertainty (sometimes also referred to as "secondary" uncertainties; see Fischbeck, 1991). For deep uncertainty, it is not possible to specify the behaviour of major components of a system because of the absence of or contradictions in data, methods, and/or theory. Decision-analytic methods can still be applied, but the process of eliciting subjective probabilities is much more complicated. The experts must factor in assessments about the likelihood of each of the alternative theories being correct, on top of assessments of the probabilities for alternative parameter values within the methods suggested by that theory. In addition, the experts need to provide some estimate of the uncertainty in outcomes caused by factors not incorporated into any existing theory. For example, there may be discontinuities in the response of the climate or ecological systems that occur at as yet unrecognized thresholds.

[2] Knight defined uncertainties as either risks accessible using objective historical data or uncertainty where there is little or no data and the underlying processes are not well understood. The exposition here updates his original taxonomy to include more recent thinking on a fuller range of degrees of uncertainties.

Since they have different starting points and objectives, the three approaches to climate policy analysis have exhibited somewhat different approaches to handling uncertainty. Applications of the cost-effectiveness approach have generally ignored uncertainty completely or stayed fairly close to the traditional decision analysis approach, focusing on incorporating a limited number of subjectively accessed probabilities on key uncertainties. Applications of the equity approach have been focused on the risks climate change and climate change policies might pose to the "most vulnerable" elements of the global population and have generally employed sensitivity analyses to accomplish this objective. Studies done from the sustainability perspective have more often than not focused on the robustness of policies (and especially those designed to build climate mitigation and adaptation possibilities) across wide ranges of values for uncertain inputs and parameters.

The rest of this chapter elaborates each of the three analytic perspectives shown in *Figure 1.1*. The motivation for this elaboration is threefold. First, it is to help the reader situate each perspective in the evolution of policy science as reflected in IPCC assessments. Second, it is designed to situate the issue of GHG emissions mitigation in the context of climate policy more broadly. Third, it seeks to locate climate policy in a broader context of concerns about development, equity, and sustainability. However, it must be emphasized that *Figure 1.1* does not represent any sort of linear evolution in which one kind of analytic tool or policy focus replaces a predecessor. Rather than a hierarchy of approaches, the evolution of perspectives suggests a portfolio approach both to assessment and policy choice. Just like a personal investment portfolio, a rational global climate policy portfolio contains a flexible mix of diverse commitments consistent with different development goals, and to protect against different contingencies at various levels of uncertainty about the future.

1.2 Cost-effective Mitigation

1.2.1 Introduction

This section describes the key themes that have been pursued by the research community working from the "cost-effective mitigation" perspective (as conceptualized in *Figure 1.2*). The focus here is on the kinds of issues that the research community working from this perspective address and not on specific results.

Researchers working from a cost-effective perspective generally focus on achieving some policy objective at minimum cost. Cost minimization, in some cases, is used to compare alternative ways to meet some climate policy objective (like a specific GHG emissions or concentration target); in other cases, alternative ways to minimize the total cost of climate change and policies designed to ameliorate its impacts are considered. In the former, the policy objective is included as a constraint; but in the latter, the objective is to minimize the cost of the climate change. In either case, the policies considered are generally restricted to those that directly affect energy use or other activities with a direct impact on GHG emissions. Although equity and sustainability metrics are frequently examined in these analyses, their inclusion usually occurs after the cost-effectiveness calculations have been completed. Exceptions to this general observation include input assumptions related to discounting and utility function parameters that do represent trade-offs between the utilities of various groups and generations. Judicious use of sensitivity analysis can, however, illuminate the trade-offs implied along these dimensions, but these trade-offs are not usually the main focus of such studies. It is therefore difficult, *ex post*, to graft other policy objectives related to development or sustainability (e.g., poverty

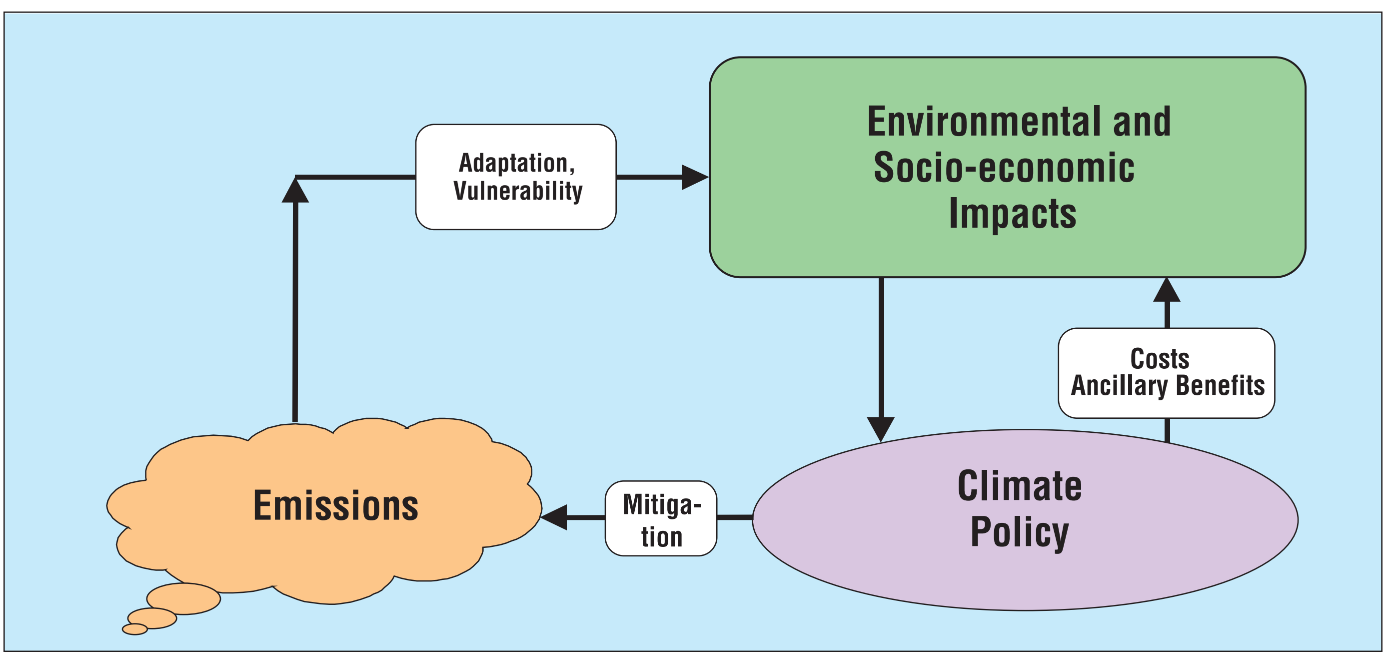

Figure 1.2: *The cost-effectiveness perspective.*

reduction, human capital development) onto a cost-effectiveness style of assessment.

1.2.2 The Costs of Climate Change Mitigation

The United Nations Framework Convention on Climate Change makes clear that cost-effectiveness is an important criterion to be used (among others) in formulating and implementing climate policies. As stated in Article 3.3 of the convention "…taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure that global benefits at the lowest possible cost (UNFCC, 1992)". The impacts of climate policy can be defined as the changes that policies cause relative to some "business-as-usual" or "baseline" situation. As discussed in Chapter 2, a baseline is a scenario of how the global or regional environments, depending on the study, will evolve over time (often over 100 years or more for baselines used in climate policy studies) in the absence of climate policy intervention. Thus, a baseline is typically built upon assumptions about future population growth, economic output, and resource and technology availability, as well as upon assumptions about future non-climate environmental policies, like controls on sulphur dioxide emissions. Changes from these baselines are frequently put into categories of "benefits" and "costs". The benefits included in the calculus are estimated from avoided climate damages and other ancillary benefits that would have otherwise occurred if mitigation policies had not been introduced. The costs for mitigation and other side effects that result are estimated from economic sacrifices that might be required to mitigate climate change.

Climate change would be a relatively simple problem to overcome if it could be avoided without sacrifice and if the means to effect this avoidance were recognized widely. At present, however, there are concerns about the sacrifices that avoiding climate change might involve. A fundamental challenge in mitigation policy analysis is thus to discern how climate change can be avoided at a minimal cost or sacrifice. Chapters 3–9 describe a number of advances since WGIII SAR that identify methods to reduce the costs of climate change mitigation. Indeed, these chapters report that some degree of mitigation might be achieved at zero cost.

Chapter 7 distinguishes several cost concepts. Opportunity cost (the value of a sacrificed opportunity) constitutes a basis upon which estimates of economic cost are constructed. The extent of the costs of mitigating climate change is, from an economic perspective, measured in terms of the value of other opportunities that must be forgone (for example, the opportunity to enjoy low prices for domestic heating or other energy services). It follows that economic costs can be different when they are viewed from different perspectives. Costs of mitigation incurred by a regulated sector are, for example, generally different from economy-wide costs. Costs are sometimes measured in currency units, but they are sometimes also measured against other metrics. In all cases, though, the underlying element of cost is the sacrifice of opportunities, goods, or services; and this element is often quite different from the overt financial outlay involved.

Chapter 7 also indicates that some notions of cost incorporate behavioural, institutional, or cultural responses that can be missed by economic analyses. In measuring opportunity costs, more specifically, economic analyses generally take personal preferences, social and legal institutions, and cultural values as given. Yet climate policies can affect (positively or negatively) the functioning of institutions. They can alter the ways in which people relate to each other; and they can influence individuals' attitudes, values, or preferences. Taking these impacts into account can alter the cost assessment. Moreover, while economic analyses (including standard benefit–cost analyses) tend to measure costs by adding up individuals' valuations of their forgone opportunities, other approaches to cost can be defined in terms that are not simple aggregations of individual measures.

As discussed below, equitable policy making brings attention to the distribution of costs as well as to their aggregate levels. There has been considerable progress since SAR in identifying ways that climate change can be avoided at lower costs. Both theoretical and modelling studies have helped to reveal the types of policies that might achieve given targets at the lowest cost. Moreover, as indicated below, models have identified certain circumstances in which at least some reductions in GHGs might be achieved at no cost.

Chapter 8 reports that the cost of mitigation can depend significantly on the selection of a designated concentration target that, typically, is assumed to be achievable within 100 or 200 years. Most model-based studies indicate that the first units of abatement are fairly inexpensive; "low-hanging fruit" is easily picked. However, most studies show that additional units of abatement require more extensive changes and involve significantly higher costs.[3] Thus, to lower the original concentration target is projected to result in a more than proportional increase in costs. Rising marginal abatement costs provide a rationale to employ broad-based, economically efficient mechanisms for GHG abatement.

The cost of mitigation depends not only upon the cumulative emissions reductions required over the next century, but on the timing of these emissions reductions as well. Chapter 8 reviews some studies that argue the most cost-effective approach to achieving a given long-term concentration target involves gradually rising abatement through time. The attraction of this approach is that it helps avoid the premature turnover of stocks of capital. In addition, deferring the bulk of abatement effort to

[3] It is possible for the cost curves to be very flat in certain regions, however, and technological change can shift them down significantly over time.

the future allows more discounting of abatement costs. However, other studies show potential cost advantages in concentrating more abatement towards the near term. These studies argue, in particular, that near-term abatement helps generate cost-effective “learning-by-doing”, by accelerating the development of new technologies that can reduce future abatement costs. These findings are not necessarily contradictory. By introducing mitigation efforts in the near term, the process of learning-by-doing is initiated. At the same time, by increasing over time the stringency of policies (that is, the extent of abatement), nations can avoid premature capital-stock turnover and exploit the cost savings from future technological advances. Chapter 10 elaborates on these issues.

It is worth emphasizing that abatement policies (such as the introduction of national targets on carbon emissions or policies to stimulate the development of energy technologies not based on carbon, as discussed in Chapter 3) can proceed in the near term even when abatement efforts are significantly deferred to the future. The near-term introduction of policies helps to stimulate efforts to bring about new technologies, which is crucial to enable future abatement to be achieved at lower cost.

As Chapter 6 discusses, individual countries can choose from a large set of possible policy instruments to limit domestic GHG emissions. These include traditional regulatory mechanisms such as technology mandates and performance standards. They also include “market-based” instruments such as carbon taxes, energy taxes, tradable emissions permits, and subsidies to clean technologies. They also include various voluntary agreements between industries and regulators. A group of countries that wishes to limit its collective GHG emissions can agree to implement some of these policies in a co-ordinated fashion.

Chapters 6–9 reveal that the costs of achieving specified mitigation targets depend critically upon the policy instrument employed. Any given target is achieved at the lowest cost when the incremental cost of emissions reduction (abatement) is the same across all emitters. If this condition is not met, then the overall costs of emissions reduction could be reduced if firms with lower incremental costs reduced emissions a bit more, and firms with higher incremental costs pursued a bit less abatement. It follows that cost-effective emissions reductions hold the promise of allowing larger emissions reductions from any allocation of resources

While market-based instruments such as carbon taxes and tradable carbon permits have potential cost advantages, the extent to which these potential advantages are actually realized depends on whether the policy generates revenues and whether these revenues are “recycled” in the form of cuts in existing taxes. Revenue recycling is important to the costs of a carbon tax, for example. When the revenues from the carbon tax finance reductions in the rates of pre-existing taxes, some of the distortionary cost of these prior taxes can be avoided; and so the cost of mitigation is reduced. These issues are further elaborated in Chapters 6–9.

The issue of revenue recycling applies also to policies that would reduce CO_2 through carbon permits or “caps”. As discussed in Chapter 6, revenues could be recycled through cuts in existing taxes if CO_2 permits are auctioned. In contrast, if the permits are distributed freely, then no revenue is collected and there is no possibility of revenue recycling. Thus, auctioning the permits has a significant potential cost advantage over free allocation.

It is also important to keep in mind that aggregate costs are not the only useful consideration in evaluating alternative policy instruments from the cost-effectiveness perspective. The distribution of these costs across businesses, regions, and individuals is important as well. Moreover, other important evaluation criteria, including administrative and political feasibility, can play a role in determining exactly how and why mitigation initiatives might emerge.

The theoretical and modelling literature also reveals that international policy co-ordination through “flexibility mechanisms” offers enormous opportunities to achieve given reductions in GHG emissions at relatively lower cost. In principle, co-ordinated policies can be designed so that cost-effectiveness is improved on a global scale. The Kyoto Protocol defines several flexibility mechanisms, including international emissions trading (IET), joint implementation (JI), and the clean development mechanism (CDM). Each of these international policy instruments provides opportunities, in theory, for Annex I Parties to fulfil their commitments cost-effectively. IET allows Annex I parties to exchange parts of their assigned amount. Similarly, JI allows Annex I parties to exchange “emission reduction units” among themselves on a project-by-project basis. Under the CDM, Annex I parties receive credit, on a project-by-project basis, for reductions accomplished in non-Annex I countries. Participation in these programmes can also increase the level of investment in clean energy technologies. International policy co-ordination in implementing climate policy also requires accounting for the “ spillover” effects of mitigation in one country that can effect economic activity in other countries through international trade linkages. In general, countries that mitigate less may gain an advantage in their share of international trade over their trading partners, but can also lose market share if those trading partners control more and thus reduce their overall level of economic activity. See Chapter 8 for more on these issues.

Most studies of national or global mitigation costs focus on CO_2 from fossil energy alone (e.g., see Chapter 8), but some recent studies consider other GHGs as well. For example, Chapters 3 and 4 discuss options to reduce emissions of non-CO_2 gases and CO_2 net emissions from land-use change, respectively. Chapter 8 indicates that defining national targets in terms of a “basket” of gases (as under the Kyoto Protocol) rather than in terms of individual gases enhances flexibility and can reduce the costs of mitigating climate change. Emissions of several of the GHGs (such as methane and nitrous oxide) from some sources can, in addition, be very difficult to monitor. This practical complication raises the potential cost of mitigation over the short- to medium-term, because it highlights the need to improve the methods used to monitor these emissions.

1.2.3 The Role of Technology

The time horizon for climate change is long. The climate impacts of decisions made in the next decade or two will be felt over the next century and beyond. As a result, technology and, more specifically, improvements in the rate and direction of technological change, will play a very important role. As discussed in Chapter 2, the development and diffusion of new technologies is perhaps the most robust and effective way to reduce GHG emissions. Three aspects of technology can be distinguished: invention (the development, perhaps in a laboratory, of a new production method, product, or service), innovation (the bringing of new inventions to the market), and diffusion (the gradual adoption of new processes or products by firms and individuals). Chapter 3 indicates that hundreds of recently invented technologies can improve energy efficiency and thus reduce energy and associated GHG emissions. These technologies can yield more energy-efficient buildings and appliances and equipment used in them. There are, however, significant barriers to their innovation and diffusion. Chapter 5 (see also IPCC, 2000a) classifies these barriers and provides a framework for understanding their connections with one another. Some new low-carbon emission technologies are not adopted because their cost and performance characteristics make them unattractive relative to existing technologies. To be adopted, these technologies require tax advantages, cost subsidies, or additional cost-reducing or performance-enhancing research and development (R&D; see Chapter 6 for a discussion of the possible efficacy of such policies). Other technologies could be adopted more rapidly if market failures and other socioeconomic constraints are reduced. Market failures refers to situations in which the price system does not allocate resources efficiently (see, e.g., Opschoor, 1997). They can emerge when information is not fully disseminated or when market prices do not reflect the full social cost. So, a new technology may not be employed if potential purchasers lack information about it or if its price lies between its private value and its, potentially higher, social value.

While Chapter 3 summarizes advances in our understanding of technological options to limit or reduce GHG emissions, Chapter 4 indicates that terrestrial systems offer significant potential to capture and hold substantially increased volumes of carbon within organic material. However, the challenges associated with defining and measuring contributions to sequestration and with monitoring the performance of individual sink projects are significant. The nature of sequestration opportunities differs by region. In some regions, the least-cost method of accomplishing sequestration is to slow or halt deforestation. In others, afforestation and reforestation of abandoned agricultural lands, degraded forests, and wastelands offer the lowest-cost opportunities. The results of the IPCC (2000c) *Special Report on Land Use, Land-Use Change and Forestry* may shed light on some of these controversies. In all cases, though, the opportunity costs associated with using terrestrial systems involve welfare implications on multiple scales.

1.2.4 The Role of Uncertainty

The uncertainties that surround climate change are vast. The connections between emissions of GHGs and climate change are not fully understood. In addition, uncertainty distorts our understanding of the impacts of climate change and the value of those impacts to humans. These uncertainties depend on scale, and become larger across the spectrum from "average" impacts across broadly defined geographical areas to specific impacts felt at a more local level.

The uncertainties that surround climate change bear on the issue of whether mitigation policies are justified. Some analysts might conclude that these uncertainties justify the postponement of significant mitigation efforts–particularly those that involve economic sacrifices–on the grounds that not enough is yet known about the problem. Proponents of this point of view argue that there is some chance that scientific inquiry will eventually reveal that the continued accumulation of GHGs will not produce significant changes in climate and/or significant associated damages. So long as the possibility exists that a "type one" error (an action that will ultimately turn out to be unnecessary) could occur, the argument goes, it is premature to undertake costly mitigation measures now.

However, uncertainty also introduces the risk that the opposite will occur. There is a significant possibility that scientific investigations will ultimately reveal that the continued accumulation of GHGs will have severe consequences for climate and substantial associated impacts. If this scenario should materialize, the cost of making this "type two" error (of taking little or no action in the near term to stem the accumulation of GHGs) could be enormous. As discussed in Chapters 8–10, it may be less costly to spread the costs of averting climate change by beginning mitigation efforts early, rather than to wait several decades and take actions after the problem has already advanced much further. Indeed, if postponing mitigation efforts allows irreversible climate impacts to occur, then no future efforts, at any cost, can undo the resultant damage.

The risks of premature (or unnecessary) action should therefore be compared with the risks of failing to take action that later proves warranted. As stated in Article 3.3 of the Framework Convention "…The parties should take precautionary measures to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects"(UNFCCC, 1992). Which risk is larger? Analyses of this issue (see Chapter 10) tend to indicate that the latter risk is sufficient to justify some mitigation efforts in the short run, despite the possibility that these efforts might ultimately prove unnecessary. These analyses depict mitigation efforts as a type of insurance against potentially serious future consequences. It is generally sensible for a person to purchase fire insurance on his or her house (despite the likelihood a fire will never occur). Likewise, it is rational for nations to insure against potentially serious damages from climate change, despite the significant chance that the most serious scenarios will not materialize.

The term precautionary principle has been employed to express the idea that it may be appropriate to take actions to prevent potentially harmful climate-change outcomes. As discussed in Chapter 10, this term has more than one meaning. A weak version of the principle is the idea that, in the presence of uncertainty, it may be prudent to engage in policies that provide insurance against some of the potential damages from climate change. Insuring against potentially serious damages can be rational simply because the costs of the insurance are less than the expected value of avoided damages. This weaker form of the precautionary principle applies even if individuals or societies are not particularly averse to risk. In its stronger form, the precautionary principle stipulates that nations should pursue whatever policies are necessary to minimize the damages under the worst possible scenario. This stronger form assumes extreme risk-aversion, since it focuses exclusively on the worst possible outcomes. It is clear, though, that there are costs associated with climate policies that could, under some circumstances, impose large costs on particular peoples and/or nations; but neither form of the precautionary principle has yet been applied to this side of the climate calculus.

Uncertainty also bears on the design of mitigation policies. As indicated in Chapters 8 and 10, the problem of climate change might be addressed most effectively through a process of sequential decision making, in which policies are adjusted over time as new scientific information becomes available and uncertainties are reduced. Moss and Schneider (2000) offer guidance on how subjective probabilities can be utilized effectively when empirical data are not available or are inconclusive. New information is valuable, and flexible policies that can make use of this information have an advantage over rigid ones that cannot. In any case, policies that help build or strengthen mitigation capacity are consistent with the insurance approach. To the extent that mitigation capacity is higher, the costs of future action can be expected to be lower.

1.2.5 Distributional Impacts and Equity Considerations

It is important to consider more than the aggregate (worldwide) benefits and costs of such policies in examining and evaluating mitigation options. Considerations of the national, intranational, industrial, and intergenerational distributions of the benefits and burdens of mitigation policies–as well as considerations of the historical contributions to the accumulation of GHGs–are crucial to develop equitable climate policies. The WGII report (IPCC, 2001) indicates that the impacts of climate change vary substantially across regions of the globe. Indeed, climate impacts can differ even on the scale of a few miles depending on geography, terrain, and other natural conditions. The costs of the economic impacts of climate policies are distributed unevenly as well, although the distribution of these impacts depends on the types of mitigation policies introduced. It is important to consider the distribution of cost impacts of different potential policies across nations, socioeconomic groups, industrial sectors, and generations.

The distribution of the economic impacts of mitigation policies across economic sectors is examined in Chapter 9. Policies such as carbon taxes or carbon caps are designed to limit carbon use and are likely to cause production, output, and employment to fall in the coal and oil extraction industries. The impact on the natural gas industry is less clear. On the one hand, a carbon tax raises the cost of supplying natural gas, which tends to imply reduced demands, output, and employment in this industry. On the other hand, this tax raises the price of coal by a larger percentage, inducing shifts in demand from coal to natural gas. The impact of mitigation policies on renewable energy sources is likely to vary by resource and region but are likely to lead to larger markets for renewables. Mitigation policies are expected to lead to structural changes in manufacturing, especially in the developed countries. Sectors that supply energy-saving equipment and low-carbon technologies are likely to benefit from these policies. Sectors that rely intensively on carbon-based fuels are expected to suffer price increases and a loss of output.

Chapter 8 indicates results that concern the distribution of impacts across household income groups. According to most studies, mitigation policies that imply higher energy prices impose higher cost-burdens (relative to income) on less affluent households than on richer households. This reflects that the poor tend to spend a larger share of their income on energy. Equity considerations suggest that mitigation policies can overcome these distributional consequences by including provisions that reduce the costs they impose on the lowest-income groups.

For the most part, existing studies of the impacts across household groups (or socioeconomic groups, more broadly) apply to developed nations. There is a severe need for studies that consider the distributional impacts within developing countries. In addition, nearly all the studies lack the detail necessary to consider impacts in socioeconomic dimensions other than income. As a result, important costs to various groups within the general population may be overlooked. Important costs may also be hidden by aggregation. This is especially relevant in studies of the impacts of climate change and mitigation activity in developing countries, since existing studies may overlook major impacts to the most vulnerable individuals. Section 1.3 discusses the issue of equity in more detail and from a broader perspective.

1.2.6 Sustainability Considerations

Sustainability considerations are typically not the primary motivation for studies carried out from the “cost-effectiveness perspective". Besides the distributional effects of climate policies, their implications for other environmental concerns can also be calculated. For example, the implied impact of climate policies on sulphur, particulate emissions, or land uses can be calculated. Sulphur emissions in some scenarios may be so high that they have major health impacts, and the land-use requirements for a global energy industry based on a very large biomass could potentially crowd out agriculture, forestry, and the recreational use of land.

As indicated in Chapter 2, the benefits and costs from a given mitigation policy depend on the baseline circumstances to which the policy is applied. The uncertainties as to what the baseline circumstances might be are vast, in the light of which it is important to evaluate the impacts of given policies relative to a range of baseline scenarios rather than to a single baseline scenario.

Human welfare and the state of the environment (which may be a determinant of human welfare, but one that is the focus of this assessment report) depend both on the baseline path and on the policy-induced departures from the baseline. A striking conclusion from Chapter 2 is that the differences in human welfare across plausible baselines can be greater than the welfare impacts of mitigation policies. That is, the nature of the baseline–which reflects a wide range of human decisions and policies outside of the climate-policy arena–can be more important than the departures from that baseline caused by climate policy. The lower the level of baseline GHG emissions, the smaller is the effort required to achieve any specific emissions or concentration target. This does not eliminate the importance of policy actions to mitigate climate change, but it reveals the importance of developments that occur outside what is typically regarded as "climate policy".

It is not surprising that changes in the economy resulting from climate policy may be small compared to changes that may occur in response to other trends in the economy and to other policies. This is so because most the GHG emissions occur in energy production, which forms a relatively low percentage of the economy (no more than 5%–10%). In principle, rearranging energy use as one element of a mitigation strategy need not be a major shock to the economy if it is done efficiently. Important also is that the costs of mitigation are likely to vary substantially among nations because of both differences in baseline emissions trends and differences in flexibility to accomplish the emissions reductions required (see also Schneider (1998) on this subject).

Deciding what counts as "climate policy" is not always straightforward, as discussed in Chapter 2. In many policy discussions, climate-change mitigation policy is assumed to involve actions for which the primary target is a reduction in GHG concentrations. These include efforts directly aimed at reducing carbon emissions, at expanding carbon sinks, at reducing emissions of other GHGs (like methane and nitrous oxide from agriculture), and at promoting the development of new technologies and production processes that rely less on carbon-based fuels (see Chapters 3 and 4). If this is the domain of mitigation policy, then other (anticipated) actions that do not fall in this category need to be regarded, by default, as part of the baseline. However, other activities have important consequences for climate change. For example, policies oriented towards local air pollution–such as controls on hydrocarbon emissions from automobiles–affect levels of emissions of CO_2 as well as the formation of tropospheric ozone, and thus have consequences for climate. Moreover, as discussed below, some policies, such as poverty alleviation, may ultimately have significant implications for the emissions of GHGs and are therefore extremely important to climate change.

The implications of different baseline assumptions about the future of the world reflect, in part, different assumptions about the sustainability of economic, biological, and social systems. Bringing them to bear on the analyses of mitigation opens the possibility that climate policies can be assessed within alternative worlds and that how climate policies might effect various measures of sustainability can be examined explicitly. This kind of analysis can support, though, only a limited treatment of sustainable development. A more in-depth treatment has been attempted by researchers working from the perspective of "envisioning transitions to sustainability"; their perspective is described in Section 1.4.

In addition to the direct benefits of GHG mitigation represented in terms of reductions in impacts resulting from climate change, the cost-effectiveness perspective also considers benefits from reductions in other pollutants[4] that may accompany the GHG emission reductions. Given the focus on climate change mitigation as the primary objective the term used most often is "ancillary benefits" (see also Chapter 8). The term "co-benefits" is used for situations where climate change and other environmental or socioeconomic objectives are equally important. That notion comes more naturally from the sustainability perspective and reflects that most policies designed to address GHG mitigation also have other, often at least equally important, rationales, e.g. related to development, equity and sustainability.

1.3 Equity and Sustainable Development

The above review of the literature on cost-effective GHG mitigation (including the chapters in this report) shows that elements of development, equity, and sustainability are addressed in some of the analyses. However, they generally take the form of boundary conditions, barriers, or constraints rather than the primary motivation of the analysis. There is also a large and growing volume of research that approaches mitigation directly from a concern with equity and development (*Figure 1.3*).

[4] In principle these ancillary benefits should be credited only to the extent of the cost of direct control of those pollutants they obviate.

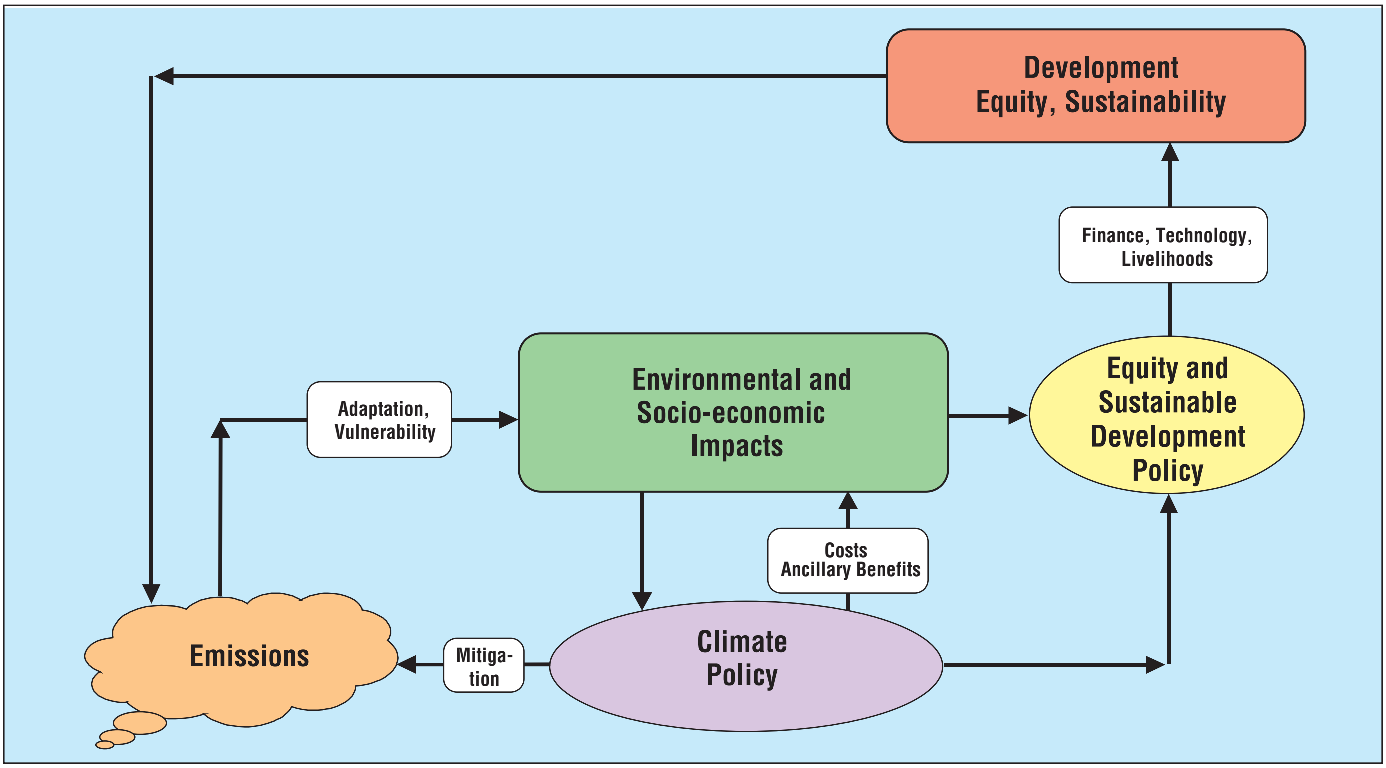

Figure 1.3: *Equity and climate change mitigation.*

While in principle, equity concerns pertain to at least three domains[5]–international, intra-country, and inter-generational–much of this literature focuses on the international dimensions of equity, and takes as its primary challenge the goal of sustainable development and poverty eradication in developing countries, (Parikh, 1992; Parikh and Parikh, 1998; Murthy, 2000).

As mentioned earlier, although this literature starts with concerns about global equity, one of its central concerns is the promotion of the prospects of sustainable development, especially in developing countries. Accordingly, we have entitled this approach, "equity and sustainable development".

An important motivation for this literature is climate change agreements in which equity–at all relevant levels (intergenerational, intragenerational, international, and intranational)–is a prominent and consistent theme. The first principle of the UNFCCC (1992, Article 3.1) states: "The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof."

The UNFCCC goes on to require developed countries to assist developing countries in coping and adapting with the impacts of climate change (Articles 4.3, 4.4, 4.5, 4.8, 4.9, 4.10), recognizes that "economic and social development and poverty eradication are the first and overriding priorities of the developing countries" (Article 4.7), and, indeed, that "Parties have a right to and should promote sustainable development" (Article 3.4). The Kyoto Protocol retained this emphasis by referring to various paragraphs of Article 4 of the UNFCCC (1992), and refrained from imposing additional commitments on developing countries (UNFCC, 1997b Article 10, preamble). It reiterated the goal of sustainable development and established the CDM to assist developing countries in achieving sustainable development while contributing to the ultimate objectives of the UNFCCC (1997b, Article 12.2; see also Jacoby *et al*., 1998; Najam and Page, 1998; Jamieson, 2000; Agarwal *et al*., 2000).

Finally, the issue of equity has been discussed not only with regard to the distribution of resources and burdens within and between generations, but also in terms of the role that it plays in the generation of social capital. Along with reproducible, natural, and human and intellectual capital, social capital is necessary for sustainability (Rayner *et al*., 1999; for related

[5] This is an extensive and diverse literature, of which a few examples are Ramakrishna (1992), Shue (1993, 1995), Mintzer and Leonard (1994), Munasinghe (1994, 1995, 2000), Lipietz (1995), Parikh (1995), Rowlands (1995), Runnalls (1995), Jamieson (1996, 2000), Murthy *et al*. (1997), Parikh *et al*. (1997), Rajan (1997), Sagar and Kandlikar (1997), Schelling (1997), Byrne *et al*. (1998), Najam and Sagar (1998), Parikh and Parikh (1998), Tolba (1998), Agarwal *et al*. (2000).

arguments, see also Hahn and Richards, 1989; Toman and Burtraw, 1991; Rose and Stevens, 1993). Fairness is integral to the establishment and maintenance of social relations at every level, from the micro to the macro, from the local to the global.

What is fair may be the subject of disagreement, but the demand for fairness only arises because of the existence of community. It is very hard to imagine what fairness would mean if we did not live and work together in families, communities, firms, nations, and other social arrangements that persist over time (Rayner, 1995).

1.3.1 What Is the Challenge?

The challenge of climate change mitigation from an equity perspective is to ensure that neither the impact of climate change nor that of mitigation policies exacerbates existing inequities both within and across nations. The starting point for describing this challenge is the vast range of differences in incomes, opportunities, capacities, and human welfare, both between and within countries. This is combined with the fact that carbon emissions are closely correlated to income levels–both across time and across nations–which suggests that restrictions on such emissions may have strong distributional effects (Parikh *et al*., 1991; Parikh *et al*., 1997b; Munasinghe, 2000).

Income and consumption, as well as vulnerability to climate change, are distributed unevenly both within and between countries.[6] Concerns about the disproportionate impacts of climate change on developing countries are mirrored in similar fears with regard to poor and vulnerable communities within developing countries (Jamieson, 1992; Ribot *et al*., 1996; Reiner and Jacoby, 1997). Similarly, issues of intergenerational equity have been raised to caution against shifting the burden of adjustment to future generations, which cannot influence political choices today (see Weiss, 1989),[7] a theme picked up in Section 1.4 below.

Academic and policy interest has focused on income distribution as well as the poverty that underlies it. Global poverty statistics are compelling. Over 1.3 billion people, or more than one-fifth of the global population, are estimated to be living at less than US$1 per day. Other measures of poverty and vulnerability–lack of access to health, education, clean water, or sanitation–yield higher estimates of poverty. Since poverty is concentrated in non-Annex I countries–especially South Asia and Africa–whose average per capita income is less than one-quarter (in dollars of constant Purchasing Power Parity) of the average for developed countries (UNDP, 1999; World Bank, 1999), equity concerns have focused on differences between rather than within countries.

The distributional dimension of global poverty was illustrated vividly by the *Human Development Report 1989* (UNDP, 1989), in the form that has come to be known as the champagne glass (*Figure 1.4*). This representation of global income distribution shows that in 1988 the richest fifth of the world's population received 82.7% of the global income, which is nearly 60 times the share of the income received by the poorest fifth (1.4%). More recent statistics indicate that inequality has widened further since then and that in 1999 the richest quintile received 80 times the income earned by the poorest quintile (UNDP, 1999).

Besides average income levels, Annex I and non-Annex I countries differ in other ways, most importantly in terms of the capacity for collective action and access to technology and finance. Many non-Annex I countries face problems of governance because of weak administrative infrastructures, failure to invest in human and institutional capacity, lack of transparency and accountability, and a high incidence of civic, political, and regional conflicts (World Bank, 1992; UNDP, 1997; Kaufmann *et al*., 1999; Knack, 2000; Thomas *et al*., 2000). They also house a less than proportionate fraction of R&D infrastructure, and consequently lack access to technology and innovation. This is especially important in issues of global environmental change, which are strongly science-driven areas (Jamieson, 1992; Ramakrishna, 1992; Najam, 1995; Agarwal and Narain, 1999). Finally, many (though not all) of these countries are over-exposed to international debt–and their governments to domestic debt–and thus have less flexibility in the choice of policy options (World Bank, 1998).

Notwithstanding the diversity of initial conditions in various countries, they share a common commitment to the goal of

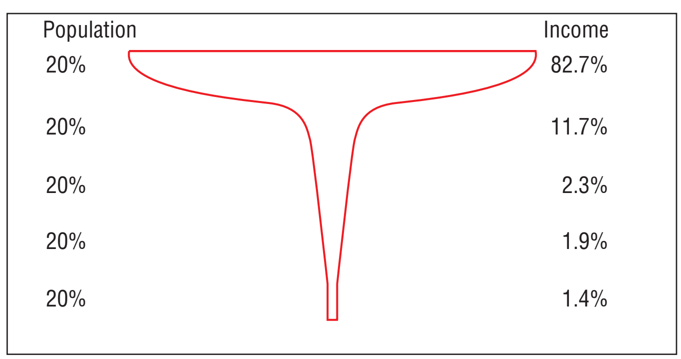

Figure 1.4: *Global distribution of income and population.*

[6] The average per capita energy consumption of low income households in developing countries is frequently only about 10% of that of the upper-middle income groups in these countries, a pattern that parallels the 1:10 ratio of per capita energy consumption between developing and developed countries (see Siddiqui, 1995).

[7] Although this issue received attention in the IPCC SAR (IPCC, 1996), the discussion was framed in technical terms, namely the determination of the appropriate discount rate, which made little accommodation for philosophical, legal, and sociological perspectives on intergenerational rights and responsibilities.

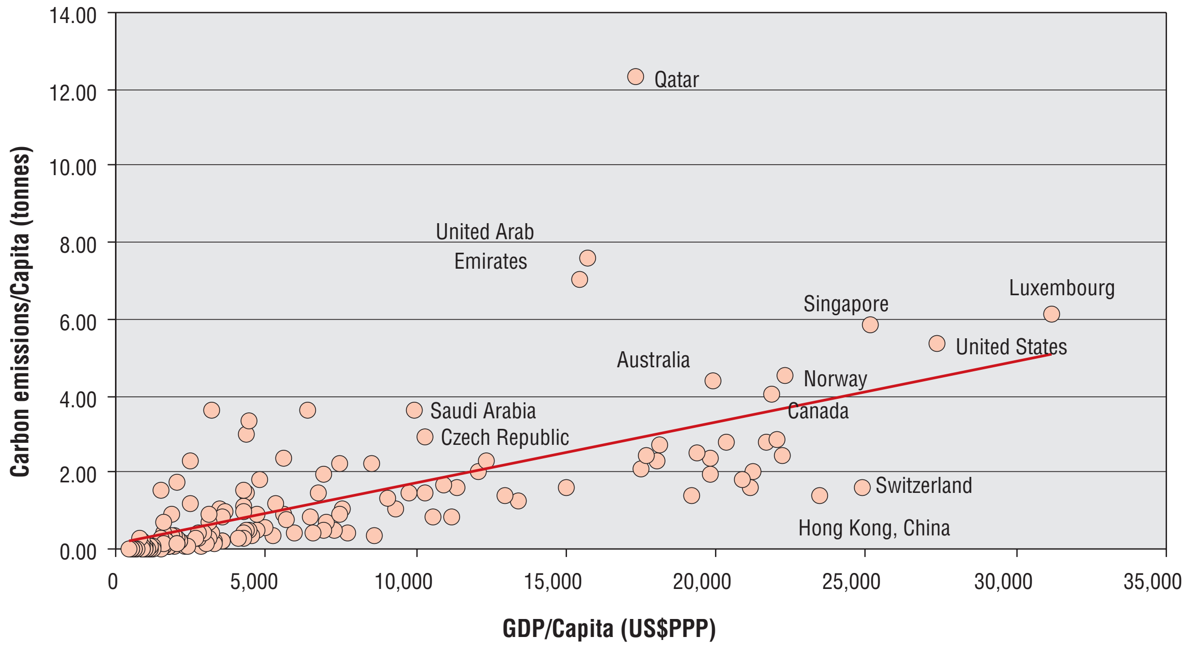

Figure 1.5: *Per capita carbon emission and income.*

economic growth, partly for its own sake and partly because it is perceived as one of the means of poverty eradication and capacity development. However, most analysts recognize that growth alone is not a solution and it needs to be combined with ancillary policies and safeguards to protect environmental and social resources. In fact, while national economic growth appears to be correlated with a reduction in poverty levels (and neutral with regard to national income distribution), over the past 50 years global income growth has been accompanied by a worsening of global income distribution (World Bank, 2000) and a persistence of poverty.[8] The concept of sustainable development has incorporated distributional aspects mainly in response to these concerns (see Lélé, 1991; Murcott, 1997). Be that as it may, economic growth continues to be the centre of government policies and plans.

This is relevant to climate change mitigation, since a fairly robust stylized fact of historical development, consistent with both cross-country and time-series data, is the close correlation between economic growth and carbon emissions. *Figure 1.5*, for example, presents cross-country data on per capita carbon emissions and income (in US$(PPP); see also *Box 1.1* on a controversy over the representation of data). The bold trend line highlights the proportionate increases (or, as in some economies in transition recently, decreases) in per capita emissions and income over time. Broadly speaking, developed countries have per capita incomes over US$(PPP)20,000 and carbon emissions between 2 and 6 tonnes per capita. Non-Annex I countries have much lower incomes and much lower emissions, while the economies in transition fall in the middle of the range. In particular, the bulk of the world's poor live in a smaller number of non-Annex I countries, which are bunched at the bottom left corner of the graph, with incomes below US$(PPP)5,000 per capita, and emissions below 0.5tC/capita.

Useful analytical tools in this regard are various decomposition approaches[9] that represent carbon emissions as the product of three factors, carbon intensity (emissions per unit of income), affluence (income per capita), and population. The decomposition suggests that reconciliation of the goals of emissions abatement and economic growth must involve a combination of population decline and technological and managerial improvements that lead to lower carbon intensity. Some potential for improvement is evident from *Figure 1.5*, namely the large differences in per capita emissions of countries and regions at the same level of affluence (e.g., Hong Kong, Switzerland, Singapore, Japan, and the USA). This suggests the possibility of technological "leap-frogging" (see Goldemberg, 1998a, Schneider, 1998), that is the lowering of emissions by a factor of two or three without impacting income levels through investment in technological development and

[8] The reason for this paradox is that at the global level intercountry distributional impacts dominate over the within-country impacts (see World Bank, 2000, p. 51).

[9] See, e.g., de Bruyn *et al*. (1998) and Opschoor (1997), who develop this idea from a development perspective, and Hoffert *et al*. (1998) who uses the "Kaya Identity" to formulate decompositions from an energy economics perspective.

capacity building.[10] However, the operational and other obstacles against the realization of these possibilities have not been analyzed systematically in the literature.

In the absence of such investment, economic growth and conventional economic development are likely to remain strongly linked to the ability to emit unlimited amounts of carbon. Therefore, restrictions on emissions will continue to be viewed by many people in developing countries as yet another constraint on the development process. The mitigation challenge, therefore, is to decouple growth and economic development from emission increases.

However, mitigation policies in general, and its decoupling from economic growth in particular, have to be designed with specific contexts in mind. Policies designed for one context are generally not appropriate for another (Shue, 1993; Rahman, 1996; Jepma and Munasinghe, 1998), and identical ultimate goals–stabilization of GHG accumulation and maintenance or achievement of the quality of life–yield different priorities and strategies in Annex I and non-Annex I countries. In the former, these goals are translated as reducing emissions while improving the quality of life, and in the latter it is the other way around–improving the quality of life, *inter alia*, by maintaining the rate of economic growth, while maintaining or lowering per capita emissions.

The current global response to this situation is to exempt non-Annex I countries from climate obligations to allow them to pursue their developmental goals freely. Furthermore, UNFCCC as well as subsequent agreements stipulate the provision of financial and technological resources for voluntary mitigation actions by this group of countries. Finally, the Kyoto Protocol created the CDM to enable developing countries to contribute to emissions abatement while pursuing sustainable development.

As non-Annex I emissions continue to grow, however, this strategy may become inadequate, and more innovative mitigation efforts might be called for in non-Annex I countries. This will mean divergences of the development path of the currently developing countries from that which developed countries have displayed (Munasinghe, 1994; Jacoby *et al*., 1998; Najam and Sagar, 1998; Barrett, 1999). As the UNDP *Human Development Report* (1998, p.7) points out, “Poor countries need to accelerate their consumption growth – but they need not follow the path taken by the rich and high-growth economies over the past half century.”

Some simple calculations can help illustrate the nature of the global mitigation challenge. Current per capita carbon emissions are slightly more than 3 tonnes per year in Annex I countries and slightly less than 0.5 tonnes per year in non-Annex I countries. With about 1.3 billion people living in Annex I countries and about 4.7 billion in non-Annex I countries, total carbon emissions are in the range of (3.1)(1.3) + (0.48)(4.7) = 6.29 billion tonnes. Thus carbon emissions at a global scale average about 1 tonne per capita per year. The stabilization of CO_2 concentrations in the atmosphere at 450, 550, 650, and 750ppmv will require steep declines in the aggregate emissions as well emissions per capita and per dollar of gross domestic product (GDP) as illustrated in the IPCC SAR Synthesis Report (IPCC, 1996). For example, based on the SAR Synthesis Report and a recent set of calculations by Bolin and Kheshgi (2000), stabilization of CO_2 concentrations in the atmosphere at 450, 550, 650, and 750ppmv would require limiting fossil-fuel carbon emissions at about 3, 6, 9 and 12 billion tonnes, respectively, by 2100 and further reductions thereafter to less than half current global emissions. If, for example, the world population stabilized at about 10 billion people by then, an average carbon emissions per capita of 0.3, 0.6, 0.9, and 1.2 tonnes of carbon would be required to achieve the 450, 550, 650, and 750ppmv limits, respectively. We make no assumption here about how these emissions would or should be allocated globally, but simply report that the average by 2100 must work out to these levels to achieve the stabilization objectives. Thus, to achieve a 450ppmv concentration target, average carbon emissions per capita globally need to drop from about 1 tonne today to about 0.3 tons in 2100; to achieve a 650ppmv target they need to drop to 0.9 tonnes (about one-quarter of current emissions per capita in the Annex I countries) by 2100 and further thereafter. Finally, with a global economy currently producing about 25 trillion dollars of output, carbon emissions per million dollars of output are currently about 240 tonnes. If, for example, the global economy grows to 200 trillion dollars of output by 2100, the emissions per million dollars (in year 2000 dollars) would need to be limited to about 10, 25, 40, and 55 tonnes of carbon in order to achieve the 450, 550, 650, and 750ppmv CO_2 limits, respectively. If further population and economic growth continues beyond 2100 additional reductions in average emissions per capita and per unit of economic output would be required.

This framing of the mitigation challenge is central to the literature on global equity and climate change. Virtually all stabilization trajectories in the literature show an initially rising trend of aggregate global emissions, followed by a declining trend; and they also show a gradual narrowing of the gap between per capita emissions of various countries and regions. In many of these scenarios, over a finite period of time, aggregate net global emissions contract to levels consistent with the absorptive capacity of global sinks, while per capita emissions of Annex I and non-Annex I countries move towards convergence in the interest of global equity. One possible international regime to achieve stabilization would initially have only Annex I emissions decline over a period of time (to make room for the growth prospects and therefore rising emissions of non-Annex I countries). At the same time, as per capita emissions

[10] This possibility is also corroborated by time-series data on carbon intensity, which reveal evidence of “de-coupling” of the strong relation in some countries, including developing countries. However, the change has not been significant enough to reverse the overall trends towards increasing emissions.

Box 1.1. A Numbers Game

A persistent theme in the literature is the explicit or implicit assignment of responsibility for global warming trends. Without going into the merits of the issue, it is useful to point out that many of the arguments revolve around the appropriate way to represent the data. For example, Agarwal and Narain (1991a) criticize the uncritical use of aggregate national emissions figures, which could imply parity between developed countries and large developing countries (China, India, and Brazil) mainly because of the large populations of the latter. Instead, they recommend the use of per capita "net emissions"–that is, emissions that exceed the per capita absorptive capacity of global carbon sinks. Other analysts distinguish between "necessary" and "luxury" emissions (Agarwal *et al*., 1999; Shue, 1993).

Another theme is the relative impact of CO_2 emissions and that of other GHGs and land-use changes, given that the latter are less strongly correlated with per capita income. Most analyses have focused on CO_2 emissions, given that it constitutes the bulk of the contribution to global warming. Others suggests that CO_2 emissions are accompanied by forced cloud changes and tropospheric aerosols, which offset their warming impact (Hansen *et al*., 2000). There are also debates over the precision of the estimates of these associated offsets, as well as those of methane emissions in developing countries (Agarwal *et al*., 1999). For example, Parikh *et al*. (1991) identify potentially serious problems with World Resources Institute's deforestation estimates (WRI, 1991); and Parikh (1992) shows how the IS92 IPCC scenarios may have been formulated with developed country interests hard-wired into them such that they could be very unfair to the developing countries. In response to this criticism some of the new SRES scenarios (IPCC, 2000a) explicitly explore scenarios with a narrowing income gap between the developed and developing countries.

Finally, "per capita" is not the only relevant normalization (Najam and Sagar, 1998), since emissions per unit of income can also indicate potential for efficiency improvements. Besides annual emissions, data can also be presented in terms of atmospheric concentrations, or the contribution to the global average temperature, each of which has slightly different implications for the responsibility for climate change. Given the uncertainties involved in constructing such estimates, the picture is not entirely clear. However, most estimates suggest that the developing countries may overtake Annex I countries, in terms of total annual emissions, in another 15–20 years, and in terms of the contribution to the global average temperature increase in 60–90 years (Hasselmann *et al*., 1993; Enting, 1998; Meira, 1999; Pinguelli Rosa and Ribeiro, 2000).

of both groups decline and converge, aggregate emissions also decline–in some scenarios to close to a carbon-free situation. There are in principle many other approaches to an equitable international regime, that are discussed in Section 1.3.2.

For the purposes of this chapter, it is convenient to divide the required emissions trajectory into three segments. Phase 1, an upward sloping segment of the non-Annex I trajectory, may require only marginal deviations in baseline emissions, for which the assessment of policy options entails a central attention to the costs and benefits of mitigation. However, for options relevant for Phase 2, a downward sloping segment of non-Annex I emissions, in which deeper cuts may be called for, global equity issues will need greater attention. Finally, the policy options that can help realize Phase 3, the asymptotic segment of the trajectory, revolve to a greater extent around sustainability concerns.

1.3.2 What Are the Options?

These considerations have given rise to a variety of solutions, both in the evolving climate agreements and in the scholarly literature. This literature classifies options in terms of the underlying theoretical and philosophical approaches to equity. Toth (1999) constructs a useful taxonomy of perspectives on equity. We have modified this taxonomy slightly into four alternative views, based on: rights, liability, poverty, and opportunity. A number of perspectives on equity are discussed more fully in Chapter 10.

Rights-based, that is based on equal (or otherwise defensible) rights to the global commons.[11] The earliest formulation of this approach was as a proposal for tradable permits (see, e.g., Agarwal and Narain, 1991a; Parikh *et al*., 1991; Grubb, 1989; Ghosh, 1993). A formulation that carries this insight to its logical conclusion is that of "contraction and convergence" (Meyer, 1999), whereby net aggregate emissions decline to zero, and per capita emissions of Annex I and non-Annex I countries reach precise equality. Initial analysis assumed an equal per capita allocation of emission permits–or rights to the "atmospheric commons"–but subsequent questioning led other writers to explore equity and efficiency implications of alternative allocation formulas, including geographical area, historic use, economic activity, or some combination of these. In all this literature, the idea is that "surplus" countries or regions, namely those (mainly among non-Annex I countries) with per capita emissions below their total allocation, could sell excess

[11] Much of the discussion on equity invokes global commons as an organizing concept, especially with regard to the conflict between individual (or corporate) use and global community interests. This is a well-worn theme in the literature on collective action, dating back to Hardin (1968), who saw unchecked population growth as the main problem. For a recent and more nuanced view, see Ostrom (2000).

emissions rights to "deficit" countries, namely those (mainly among the Annex I countries) that exceed their quota. Besides a transfer from rich to poor countries, this scheme provided incentives to both groups to reduce their emissions–at least as long as emissions rights are a scarce commodity–to reap the financial benefits of conservation. In other words, it sought simultaneously to reward restraint, punish profligacy, provide incentives for conservation, induce a transfer from rich countries to poor ones, and thus lead to distributional equity, efficiency, and sustainability.

Liability-based, that is based on the right of people not to be harmed by others' actions without suitable compenzation (see Rayner *et al*., 1999).[12] This literature focuses on the damage caused by overuse of the commons, and seeks to establish mechanisms through which those who cause such damage are penalized and the victims of the damage compensated. This perspective opens up possibilities of financial instruments, such as insurance, which distribute risk across society. Countries or groups that believe that the risk of harm is overstated could offer insurance to others against the liability (Sagar and Banuri, 1999). In other words, this solution is expected to lead to sustainability (incentive for restraint) and procedural (though not necessarily distributional) equity. However, broadly speaking, the climate negotiations have not taken this route in any significant manner.

Poverty-based, that is based on the need to protect the poor and vulnerable against the impact of climate change as well as climate policy. Roughly 2 billion people in the world exist at levels of consumption that, from the CO_2 emissions perspective, do not pose a threat to the climate (although their lifestyles are a threat to their own survival).[13] Unlike the high-technology sectors of the developed as well as developing countries, the poor and vulnerable communities lack the flexibility to adapt to global changes or global agreements. Options based on this approach include investment in capacity building and protection for the poor and vulnerable groups to enable them to enhance their livelihoods in an emerging climate regime, while setting aggregate emission targets for the rest of the world. This could also involve a transition to renewable energy in the developing countries, which is generally consistent with the sustainable livelihoods perspective, especially since the current menu of renewable energy technologies includes many that are small scale and appropriate for scattered and low-income populations. Elements of this solution are contained in Agenda 21, but it has not otherwise played a prominent role in discussions of global climate regimes or global governance–except for the occasional reference to intranational equity (see, e.g., Rayner and Malone, 2000).

Opportunity-based, that is based on the right of people, not to the global commons *per se*, but to the opportunity to achieve a standard of living enjoyed by those with greater access to the commons (see e.g., Najam, 2000). It has strong overlaps with the compromise solution that is emerging from the negotiations. Its exclusive focus is on the relationship between states, and it has led to agreements that place the burden of adjustment primarily on Annex I countries. It also implies a tacit consensus on such matters as:

- no large financial transfers or windfall gains;
- no sudden shocks, but a gradual approach consistent with the coping capacity of different countries;
- no financial burden on non-Annex I countries; and
- no restrictions on the space for sustainable development, particularly in the developing countries.

1.3.3 How Has Global Climate Policy Treated Equity?

Indeed, some elements of the equity agenda–primarily at the international level–have been incorporated into the emerging global climate policy regime. In particular:

- initial mitigation efforts have been concentrated in Annex I countries, resulting in a search for the most cost-effective solutions as detailed in Section 1.2;
- currently, non-Annex I countries are exempt from specific mitigation obligations;[14]
- there are agreements to provide financial resources to non-Annex I countries to cover the full cost of preliminary climate obligations (e.g., monitoring, reporting, and planning), and the incremental cost of voluntary mitigation actions;
- there are agreements and some programs to provide technical assistance and training to identify potential win–win opportunities;
- various voluntary mechanisms are being designed to induce early mitigation action in non-Annex I countries, most notably including the CDM of the Kyoto Protocol.

While the details of the CDM are still to be worked out, in broad terms it allows entities in Annex I countries to fulfil their

[12] In the literature cited by Rayner *et al*. (1999) see, in particular, Grubb (1995), Burtraw and Toman (1992), and Chichilnisky and Heal (1994). For a theoretical framework on accident liability, see Calabrese (1970).

[13] This group has been referred to in the literature as the "ecological refugees" (Gadgil and Guha, 1995), the "vagabonds" (Bauman, 1998), the "castaways" (Latouche, 1993), and the "excluded" (Korten, 1995). However, some writers have raised concerns that these groups impact climate change (as well as biodiversity) adversely through non-sustainable land-use practices and deforestation.

[14] However, current trends suggest that mitigation has already begun in some non-Annex I countries, even in the absence of deliberate climate policy. Reductions on fossil fuel subsidies (as a percentage of existing subsidies) have been larger in developing countries (especially China) than in OECD countries, and are leading to considerable savings in carbon emissions (International Energy Agency, 1996; Johnson *et al*., 1996; Reid and Goldemberg, 1997).

mitigation obligations through co-operative investment in non-Annex I countries, presumably at a lower cost. It has been hailed by some analysts as an ingenious device to reconcile the goals of GHG abatement and sustainable development (see Goldemberg, 1998b; Haites and Aslam, 2000). On the other hand, it has also generated a degree of criticism. Critics fear that:

- CDM will channel investment into projects of marginal social utility (Agarwal and Narain, 1999);
- gains will not be shared fairly (Parikh *et al*., 1991, 1997a; Parikh, 1994, 1995);
- technology transfer will not be satisfactory (Parikh, 2000);
- poorer countries (especially African countries) and vulnerable groups will be excluded (Sokona *et al*., 1998, 1999; Goldemberg, 1998b);
- only resources for cheap mitigation options will be attracted (the so-called "low-hanging fruit"), leaving developing countries to undertake the more expensive options themselves (Agarwal *et al*., 1999);[15]
- CDM will lead to an effective relaxation of the emission caps (Begg *et al.*, 2000; Parkinson *et al.*, 1999), and
- paradoxically, it may compromise the capacity of developing countries to pursue sustainable development (Banuri and Gupta, 2000).

Going beyond the current options, such as CDM, and to a longer time horizon raises the need to integrate mitigation goals within the broader (sustainable) development agendas of developing countries (Najam, 2000). An emerging literature has begun to explore this redefined problem (see Munasinghe, 2000). Some issues that are relevant to this discussion include:

- *Scale*. The scale of the mitigation challenge in non-Annex I countries is projected to be much broader in the long term than the short term. Instead of an exclusive reliance on financial and technological assistance, which ordinarily indicates increases in assistance levels significantly above historical trends, there is a need to invest in indigenous capacity to undertake mitigation without compromising the development agenda.
- *Timing*. To sustain the interest of both developed and developing countries in co-operative solutions, the goal must be to lower the cost of mitigation over time rather than to concentrate simply on exhausting the cheap mitigation options (the so-called "low-hanging fruit").
- *Relevance to economic growth and sustainable development*. Recent studies of the impact of foreign resource inflows demonstrate that these flows alone do not suffice to promote economic growth or sustainable development without appropriate policy and institutional environments (World Bank, 1998). It is not clear whether financial resources alone will lead to climate mitigation and economic growth.
- *Equity and trust*. Despite consistent and repeated references to equity in climate agreements, sceptics remain wary that equity will eventually be subverted in some way and involuntary obligations imposed on non-Annex I countries (without financial compenzation) to force them to bear a disproportionate burden of mitigation (Agarwal and Narain, 1991a; Hyder, 1992; Parikh, 1992; Dasgupta, 1994; Parikh, 1995; Parikh and Parikh, 1998; Agarwal *et al.,* 1999).[16]

Some scholars propose remedies to reconcile these longer-term concerns with the more immediate goals of the existing agenda. The simplest is a proposal to restrict all co-operative measures–and thus all early and voluntary action in non-Annex I countries–to "non-carbon" projects (Agarwal and Narain, 1999). While this would exclude some legitimate mitigation options from the purview, it could channel research and entrepreneurial resources into a new market, bring down unit costs, create and strengthen technical and managerial capacities, and thus enable both developed and developing countries to engineer a transition to a carbon-free future. Renewable energy projects have been implemented at smaller scales, which make them appropriate for poor rural communities. Other proposals similarly address the potential co-benefits of the protection of primary forests (see Kremen *et al.,* 2000).

1.3.4 Assessment of Alternatives: Sustainable Development

While the motivating concern of the perspective described in this section is that of global equity, the literature included here has also sought to incorporate concerns of efficiency and sustainability. The main mechanism through which this has been accomplished is by using equity considerations to argue for the protection of the prospects of sustainable development in developing countries. Such an agenda is equivalent to a non-co-ordinated pursuit of sustainability in each country, as well as the formulation of policies that promote economic growth and resource efficiency.

This is analogous to the discussed in Section 1.2, in which it was shown that the cost–benefit perspective enables the assessment and comparison of alternative policy options from an efficiency standpoint. Analogously, the progression from glob-

[15] However, defenders of the CDM argue that the current options will disappear if not exploited immediately (for the "low-hanging fruit" will rot if not picked early), and that the early exploitation will transfer technology, capacity, and resources to developing countries and enable them to access the more expensive options later (see Haites and Aslam, 2000).

[16] For example, several authors have commented on the initiation of attempts at Kyoto to incorporate developing countries within an emissions control mandate as a retreat from the foundational principles of the UNFCCC (Cooper, 1998; Jacoby *et al*., 1998; Schmalensee, 1998). These attempts include the call for the adoption of voluntary emissions control targets by non-Annex 1 countries (UNFCCC, 1997a).

Box 1.2. Sustainable Development

The term "sustainable development" was popularized in academic and policy circles by the Brundtland Report (WCED, 1987), although its distinctive antecedents predate the report (especially IUCN, WWF, and UNEP, 1980). The Brundtland Commission defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8). However, although the ubiquity of references to this definition suggests a degree of scholarly consensus, this is not the case. There is considerable disagreement on conceptual grounds and, perhaps most significantly, on its operationalization (see Lélé, 1991). Nevertheless, most scholars and practitioners accept a concern for economic prosperity (development), ecological integrity (sustainability), and social justice (equity) as the three pillars of sustainable development (Buitenkamp *et al*., 1992; Opschoor, 1992; Munasinghe, 1993, 2000; Banuri *et al*., 1994; Munasinghe and Shearer, 1995; Elkington, 1997; Carley and Spapens, 1998; Sachs *et al*., 1998; Sachs, 1999).

Sustainable development is an integrating concept (Lélé, 1991; Perrings, 1991; Dietz *et al*., 1992; Munasinghe, 2000) that has emerged gradually (Rayner and Malone, 1998a , 2000; Costanza, 1999; Munasinghe, 2000; Pichs-Madruga, 1999). Initially, the environmental, economic, and social domains were treated independently, and sustainability viewed as their sum or union. More recently, with the shift in emphasis towards practical and operational aspects, the literature has begun to look at synergies and trade-offs between the three goals.

al equity to sustainable development enables the comparison of policy options that emanate from concerns about global equity. This framework has evolved precisely to enable the assessment of the synergies and trade-offs involved in the pursuit of multiple goals–environmental conservation, social equity, economic growth, and poverty eradication (*Box 1.2*). These analyses touch upon many of the themes relevant to an assessment of the broad range of policy options described above–time horizon, uncertainty, and welfare.

Sustainable development is one of a series of innovative concepts–following such antecedents as human development, equitable development, or appropriate development–that seek to broaden the scope of development theory from its narrow focus on economic growth.[17] However, this evolution has not led to a radical transformation in the operational dimensions of development planning. The focus still continues to be the stock of capital–which in many ways serves as the proxy for welfare or as the index of the "real" or "permanent" income of a society (see Johnson, 1964). As such, much development policy concentrates on measures that stimulate investment and expand the stock of capital. Each innovation has served mainly to expand the definition of the capital stock.

Sustainable development, being the most recent in the series of conceptual advances, subsumes the earlier ones, and rather than meaning simply "development plus natural resource conservation", includes human development, poverty eradication, and social equity as well. Accordingly, it expands the definition of the capital stock to include human capital (skills), natural capital (natural resources and biodiversity), and, most recently, social capital.[18] In principle therefore, sustainable development is equivalent to investment in this composite stock of capital. However, there are differences of approach rooted in the persistent controversies in development thinking. Some authors focus on investments in all relevant forms of capital, while others focus on the capacity to make such investments. Similarly, the degree of substitution that is possible between kinds of capital -- for example, between natural and human capital -- is a subject of disagreement among researchers. (see *Box 1.3*).[19]

It might appear from the above that sustainable development entails a trade-off between investment in physical capital, social capital, and natural capital, and therefore between economic growth, income distribution, and environmental conservation. However, some branches of development theory have ceased to view these as trade-offs. In particular, the goal of the research on sustainable development–especially conservation strategies and action plans–is to show that under appropriate institutional and social conditions there is a synergy rather than conflict between different goals (IUCN, WWF, and UNEP, 1980). Even earlier, development analysts had begun to question the supposed trade-off between economic growth and income distribution (World Bank, 2000; see also Kuznets, 1955; Hicks, 1979; Chenery, 1980; Fields, 1980).

These debates stem from the earliest days of development thinking, in which a distinction was made between the "bal-

[17] These innovations have also yielded alternative indices of welfare, including the human development index (HDI; see UNDP, 1989), basic human needs (BHN; see Streeten *et al*., 1981), the physical quality of life index (PQLI; see Morris, 1979), and others.

[18] "Social capital" is generally taken to mean the network of social relationships, collective social capacities, and institutions (Banuri *et al*., 1994; Clague, 1997).

[19] In the absence of detailed data that would (or, indeed, could) allow the aggregation of the different components of the capital stock into a single index, the only option is to pay attention to each component separately. The "four capitals" approach has remained largely a conceptual device rather than an operational one, even though it has often been applied at a project level to ensure that all the necessary components are accounted for.

Box 1.3. Approaches to Understanding Sustainability

Economists distinguish between four main components of the resource base: natural capital (natural resource assets), reproducible capital (durable structures or equipment produced by human beings), human capital (the productive potential of human beings), and social capital (norms and institutions that influence the interactions among humans). These are called capital because they are durable assets capable of generating flows of goods and services. In this construction, development is sustainable if some aggregate index across all forms of capital is non-decreasing.

Strong Sustainability. The strong sustainability approach of the so-called London school (Pearce, 1993) holds that different types of capital are not necessarily substitutable, so that sustainability requires the maintenance of a fixed (or minimum) stock of each component of natural capital. Under this notion, any development path that leads to an overall diminishment in the stocks of natural capital (or to a decline below the minimum) fails to be sustainable even if other forms of capital increase.

Weak Sustainability: The weak sustainability approach asserts that the different forms of capital can substitute for one another to some degree. The substitutability of different types of capital implies that the preservation of an aggregate level of capital, rather than the preservation of natural capital in particular, is crucial. The weak sustainability approach is consistent with the idea that some loss of "climate capital" could be consistent with sustainability if increases in other forms of capital could compensate for the loss.

anced growth" advocated by some writers (Rosenstein-Rodan, 1943; Nurkse, 1958), and the strategy of "unbalanced growth" advanced initially by Albert Hirschman (1958). Hirschman argued that growth is a disequilibrium process, which occurs through the efforts of economic agents to overcome bottlenecks that emerge during normal economic activity. Therefore, policy should not be restricted merely to the mobilization of financial transfers and transfer of technology, but should focus on the larger goal of creating the capacity for mobilizing and allocating such resources,[20] in effect to create conditions in which economic agents can most effectively respond to bottlenecks.

It is fair to say that the development profession has increasingly invoked themes from the latter approach. The emphasis has shifted from promoting growth towards promoting the capacity for growth. Development policy is concerned increasingly with conditions that stimulate investment–trade liberalization, structural adjustment, skill development, governance, institutional development, and market access–rather than the investment itself. This is partly because the fashion has changed from public to private investment, and partly because a large body of research shows that, while the scarcity of financial resources can inhibit the growth process, inflows do not necessarily promote it (Bauer and Yamey, 1982). For example, a recent review of cross-country experience (World Bank, 1998) discovered that the net impact of foreign resource inflows depends critically on ancillary factors–the nature of domestic policies, the fiscal stance, the institutions of governance, and the openness to international trade flows. "Successful" foreign aid led to US$2 of additional private sector investment for every dollar of aid, while in "failed" cases foreign aid was associated with a net decline in private investment.

Similar shifts have occurred in other areas of development theory and practice. The operationalization of sustainable human development, for example, is increasingly argued to consist not of the simultaneous pursuit of several independent goals, but of investments in social capital to enable the other goals to be pursued through normal market or regulatory mechanisms (Banuri *et al*., 1994). Poverty eradication programmes focus increasingly on institutional development rather than the creation of physical or social infrastructures. They concentrate on the fact that poor and vulnerable groups generally lack formal organizational structures and recognition as well as the capacity to respond to market opportunities.[21]

1.3.5 *Why Worry about Equity and Sustainable Development?*

While many consider equity to be a good thing in and of itself, this alone may not be reason enough to include it within the context of climate change mitigation. The literature on equity and climate change tends to argue rather that the pursuit of equity will help generate support for mitigation efforts; and that by enabling the pursuit of sustainable development within individual countries, it will lead to more effective mitigation (Lipietz, 1995; Rowlands, 1995; Runnals, 1997; Shue, 1995; Jamieson, 1996, 2000; Byrne, *et al*., 1998; Parikh and Parikh, 1998; Tolba, 1998; Agarwal *et al*., 1999). Given that develop-

[20] "Capacity" is different from "capital", although the two are related. The latter implies the availability of income-generating capacity alone, while the former suggests the freedom to make policy choices or to achieve social goals.

[21] Indeed, some analysts argue that the poor constitute a distinct "livelihood" economy, which is not well integrated into the global trading and financial system, and therefore lacks the flexibility to respond to emerging market opportunities or standard economic policies (Korten, 1990, 1995).

ing countries have a large suite of pressing social and economic concerns besides emissions control (Najam, 1995; Runnals, 1995; Tolba, 1998), they tend to be wary of mitigation policies lest they undermine other policy goals. Support for sustainable development, besides its own merits, can generate support for climate policy as well. While global climate policy seeks to push the Annex I countries towards emissions contraction, global sustainable development policy offers the opportunity to nudge the developing countries towards a potentially "convergent" trajectory.

Of course, the question is not simply of nudging and pushing countries towards an ultimately equitable path, but to arrive at a global stabilization that is both equitable and sustainable in the long run. Reaction to the Kyoto targets (Malakoff, 1997) suggests that this would require much more than just slight pushing and nudging. A growing literature suggests that this process would be helped by a the longer term focus on sustainability and the alternative development pathways that could lead to it. This is the subject of the next section.

1.4 Global Sustainability and Climate Change Mitigation

In Sections 1.2 and 1.3, we examined literature that was motivated primarily by concerns of global cost-effectiveness and global equity respectively. We now turn to a third category of literature, which is motivated largely by considerations of global sustainability. This literature views the climate problem as a component of a larger problem, namely the unsustainable lifestyles and patterns of production and consumption, and explores a broad range of options for moving the world towards a sustainable future (*Figure 1.6*).

1.4.1 Alternative Development Pathways

The modes of analysis in the studies reviewed in Sections 1.2 and 1.3 start, by and large, with existing institutions and behaviour, and examine their implications for future outcomes. The literature discussed in this section adopts a different approach. It starts with desirable outcomes and examines actions and institutions from the point of view of their compatibility with desirable outcomes. It seeks to fulfil a different objective. It aims to create shared visions of sustainable and desirable societies among the general public, and so it does not, in the first place, suggest implementation alternatives for fixed goals to decision makers (Costanza, 2000). To enlarge the range of accessible options in future decisions, authors who contribute to this line of inquiry intend to foster a process of societal learning among citizens. After all, value formation through public discussion is, as Sen (1995) suggests, the essence of democracy. In doing so, the work of these authors comple-

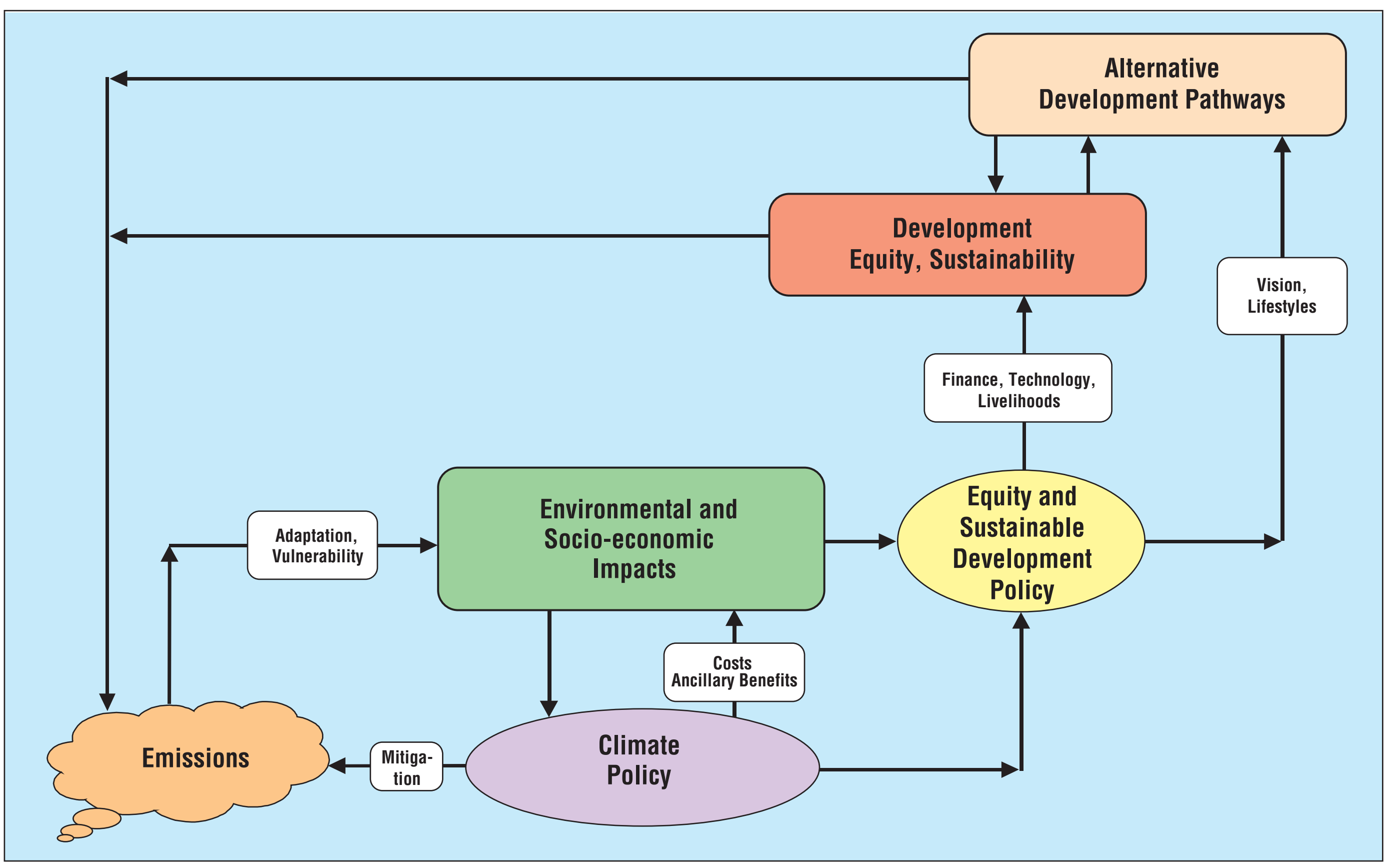

Figure 1.6: *The global-sustainability perspective.*

ments the studies discussed above by providing alternative frameworks, normative contexts, and sets of methodological tools to assess (a broader range of) policy options. Conceptually speaking, this literature takes two forms. The first offers visions of the future based on the inter-relation of various factors across a long time-scale. The second explores possible elements of future scenarios, often relying upon the extrapolation of the existing experience with sustainable practices.

The bulk of this literature starts with the recognition that long-term sustainability can imply an appropriate scale of resource flows, in society (Daly, 1997). Taking a society of appropriate physical scale as a desirable future, this literature goes on to works backwards (backcasts) through possible development paths that may lead from present-day society to a more sustainable, and in the case of concerns about climate change, low-carbon society. Authors who write from this perspective usually assume that resource availability, technology, and society move forwards in a co-evolutionary fashion (Norgaard, 1994). They work on the hypothesis that the transition to balanced and sustainable resource flows implies concomitant changes in technologies, institutions, lifestyles, and worldviews. Though this research takes a certain state of sustainability as its point of departure, it is also sensitive to the principles of equity and cost-effectiveness. It tends to view these as second-order principles that provide structure to the pursuit of sustainability, the first-order principle. In a sense, this literature can be viewed as the mirror image of the studies reviewed earlier–studies that justify the pursuit of sustainability on the grounds of efficiency and equity.

This perspective becomes relevant when it is placed in the context of concerns about unsustainability (loss of biological diversity, extinction of species, air and water pollution, deforestation, desertification, persistent poverty, and rising inequality both within and between nations, and so on). These concerns are derived from underlying pressures imposed by the growth of consumption and population and the inability of many people and communities to protect their health and livelihoods against these damages. Climate change is thus a potentially critical factor in the larger process of society's adaptive response to changing historical conditions through its choice of developmental paths (Cohen *et al*., 1998, p. 360). Chapter 2 of this report (based on the IPCC (2000a) Special Report on Emissions Scenarios (SRES)) notes, for example, that future emissions will be determined not just by climate policy, but also and more importantly by the "world" in which we will live. Decisions about technology, investment, trade, poverty, biodiversity, community rights, social policies, or governance, which may seem unrelated to climate policy, may have profound impacts upon emissions, the extent of mitigation required, and the cost and benefits that result. Conversely, climate policies that implicitly address social, environmental, economic, and security issues may turn out to be important levers for creating a sustainable world (Reddy *et al*., 1997, p. 6).

Backcasting from desirable future conditions can, according to Thompson *et al*. (1986), be a useful response to situations characterized by a high degree of ignorance, for which it is difficult to assess the probabilities of possible outcomes or even to know what those possible outcomes might be. Although there is a scientific consensus that anthropogenic climate change is occurring, there is considerable uncertainty about the rate of expected change and its manifestations and impacts at the regional and global levels (see IPCC, 2001, Chapter 19). Science cannot predict the climate and its impacts in Milwaukee, Mumbai, or Moscow half a century ahead very accurately, and it may never be able to do so. Moreover, these types of predictions also require scenarios of the social, economic, and technological paths that the world will follow over the same period (see Chapter 2)–knowledge that may be further beyond our reach than climate prediction. Moreover, this uncertainty increases with the time scale.

The high degree of uncertainty under which climate policy must be developed has important implications for the type of policy regimes likely to be most effective. There is a high degree of uncertainty about how ecosystems would respond to climate change in the studies reviewed here. This recognition suggests that a portfolio approach that includes a broad range of policies diversified across all the major uncertainties might be better than betting on any one particular set of outcomes. Some studies have even drawn a direct parallel between the value of biological diversity and the diversity of institutions and worldviews that contribute to the social capital necessary to maintain the sustainability of human societies (Rayner and Malone, 1998b). Stressing the relationship between risk, resilience, and governance, these authors argue that rather than seeking to anticipate and fix particular problems, the purpose of policy should be to develop coping capacity. This would both switch development and environmental management strategies more nimbly as scientific information improves and strengthen the resilience of vulnerable communities to climate impacts. Conditions of deep uncertainty make it rational for societies to focus on increasing their resilience and flexibility. Resilience in the face of unknown challenges, this research argues, may be achieved by relying on the formation of values and worldviews that embrace the goal of long-term sustainability, at least until some of the key uncertainties are resolved to the point that pursuit of a more narrowly focused policy regime can be justified.

Backcasting from a sustainable future state also supports the search for options with which certain normative goals might be achieved. For climate mitigation scenarios, such a goal might be expressed as a hypothetically acceptable stabilization threshold for GHG concentrations that may, in turn, imply certain trajectories for emission reductions. At this point, therefore, it is useful to review the historical data of global and regional carbon emissions in aggregate as well as in per capita terms (*Table 1.1*; see also *Box 1.1* on the controversy over presentation of data). In 1996, aggregate global emissions were about 6GtC, that is about 1 tonne of carbon per capita world-

Table 1.1: *Per capita income and carbon emissions in various regions*

Reference case, 1990 to 2020 (MtC)						
Region/Country	**History**		**Projections**			**Average annual change (%)**
	1990	**1996**	**2000**	**2010**	**2020**	**1996 to 2020**
North America	1550	1687	1833	2079	2314	1.3
USA	1346	1463	1585	1790	1975	1.3
Canada	126	140	151	162	182	1.1
Western Europe	936	904	947	1021	1114	0.9
Industrialized Asia	364	389	377	435	479	0.9
Japan	274	291	273	322	358	0.9
Australasia	90	99	103	113	122	0.9
Total Developed	**2850**	**2980**	**3157**	**3535**	**3907**	**1.1**
Former Soviet Union (FSU)	991	613	583	666	746	0.8
Eastern Europe (EE)	299	228	243	270	277	0.8
Total EE/FSU	**1290**	**842**	**827**	**935**	**1024**	**0.8**
Developing Asia	1065	1474	1659	2426	3377	3.5
China	620	805	930	1391	2031	3.9
India	153	230	273	386	494	3.2
Middle East	229	283	323	434	555	2.8
Africa	178	198	214	270	325	2.1
Central and South America	174	206	251	418	629	4.8
Total Developing	**1646**	**2161**	**2447**	**3547**	**4886**	**3.5**
Total World	**5786**	**5983**	**6430**	**8018**	**9817**	**2.1**

wide. Of this, the 1.2 billion people living in Annex I countries emitted roughly 64% (3.8GtC), or an average of about 3 tonnes of carbon per capita (3tC/capita). In contrast, 4.4 billion people living in non-Annex I countries were responsible for the remaining 2.1GtC, averaging only 0.5tC/capita, or about one-sixth the average for richer countries. Global emissions increased from 5.8GtC to 6GtC from 1990 to 1996, and are projected to increase to 6.4GtC in 2000 and 9.8GtC in 2020.[22] Non-Annex I emissions are growing much faster than those of Annex I countries, averaging 3.5% annual growth compared with 1% in Annex I. As a result, the Annex I share of emissions is declining–from approximately 72% in 1990 and 64% in 1995 to a projected 50% in 2020.

Table 1.2 provides long-term information by displaying aggregate emissions budgets for IPCC SRES scenarios (IPCC, 2000a) and for various stabilization goals identified in the SAR (IPCC, 1996). These goals translate into a 100-year emissions "budget" of 630GtC–13,00GtC. As discussed in section 1.3.1, the target of 450ppmv translates into a reduction (by 2100) of annual emissions to about 3GtC; that is reductions in annual emissions to half of the current level of about 6GtC. Simply stated, per capita emissions of all countries have to fall below current levels in developing countries if GHG stabilization at low levels is to be the targetted future. If these reductions were shared equally, per capita emissions of developed countries would decline by a factor of 10, while emissions from developing countries would halve[23].

These issues, as well as others with purviews beyond the confines of climate change, can provide a starting point for a variety of approaches and analyses. The studies reviewed here investigate kinds of behaviour, institutions, values, technologies, and lifestyles that would be compatible or incompatible with a "desirable" or targetted future. They argue, implicitly or explicitly, that sustainability is built on societal goals made

[22] EIA, *Energy Outlook*. These scenarios do not account for the impact of the recent agreements in Kyoto to curb emissions. The differences in trends in Annex I and non-Annex I are similar in other baseline scenarios. Chapter 2 discusses the range of possible scenarios and criteria for selection.

[23] While in the previous section on the equity perspective the emphasis is on an equitable distribution of greenhouse gas emissions while taking into account sustainability criteria, in this section on global sustainability the focus is on the implications of an eventual decrease of global per capita emissions taking into account equity criteria.

Table 1.2. Comparison of cumulative carbon emissions in SRES scenarios and SAR

SRES baseline scenarios	Total emissions 1990 to 2100 (GtC)
B1	989
A1T	1038
B2	1166
A1B	1437
A2	1773
A1FI	2128
IPCC SAR stabilization scenarios (Stabilization level in ppmv CO_2)	**Total emissions 1990 to 2100 (GtC)**
450	630–650
550	870–990
650	1030–1190
750	1200–1300

mutually supportive early in the process, when the goals and policies of society are being set, rather than downstream after the costs of unsustainable development have already been incurred (Schmidt-Bleek, 1994; Factor 10 Club, 1995). For this reason, they often adopt the industrial metabolism approach, focussing on the flow of materials and energy in modern society through the chain of extraction, production, consumption, and disposal (Ayres and Simonis, 1994; Fischer-Kowalski *et al*., 1997; Opschoor, 1997). It is argued that the pressure the human economy exerts on the environment depends on levels and patterns of these flows between the economy and the biosphere. Within this conceptual framework, sustainability requires reductions in the overall level of resource flows, particularly the primary flow of (fossil) materials and energy at the input side. Trajectories of emissions reduction of the sort described above can, therefore, be taken as rough indicators for the order of magnitude of the changes involved in the transition to long-term sustainability. In light of this perspective, a number of studies of developed countries (Buitenkamp *et al*., 1992; McLaren *et al*., 1997; Carley and Spapens, 1998; Sachs *et al*., 1998; Bologna *et al*., 2000) have attempted to backcast a transition to a society capable of creating human welfare with a constantly diminishing amount of natural resources. Certainly, scenarios that explore such outcomes are not restricted to decarbonization or a trend toward carbon sequestration. They may, however, view policies that facilitate these trends as vehicles for nudging the world towards a sustainable future.

All of these scenarios proceed on the premise that economic growth (at least as currently measured) is not the sole goal of societies across the globe. Moreover, they assume that the relationships between economic growth and resource consumption, on the one hand, and wellbeing, on the other, are not fixed. Both should, instead, be shapable by political and social design. A given level of gross domestic product (GDP) can be achieved with different resource flows (Adriaanse *et al*., 1997),[24] and economic growth that takes societies beyond certain subsistence levels may not increase satisfaction, or human welfare (UNDP, 1998), or societal welfare (Cobb and Cobb, 1994; Linton, 1998). Consequently, the purpose of these visions is to explore how societies might be able to decouple economic output from resource flows (see Weizsäcker *et al*., 1997; OECD, 1998) and wellbeing from economic output (see Robinson and Herbert, 2000). Climate change mitigation is one of the co-benefits of these decoupling processes.

1.4.2 Decoupling Growth from Resource Flows

A considerable literature has emerged recently on experiences with technologies, practices, and products that increase resource productivity and ecological efficiency, and thereby reduce the volume of resource input per unit of economic output. The ultimate hope is to shed light on ways in which economic growth and social security can be sustained while resource flows decline in developed countries and/or grow more slowly in developing countries. This literature cites macroeconomic trends with relative reductions in the intensity of resource use coupled with slight increases in absolute levels in the developed economies (Adriaanse *et al*., 1997). It deals with issues that are central to alternative development paths that are also discussed in the SRES (IPCC, 2000a) and chapter 2. It also notes leapfrogging phases of technological development for developing economies (UNDP, 1998, p. 83). On the micro level, it identifies experiences with cleaner, more economical energy systems, and the potential for information technology to increase resource efficiency. In either case, authors

[24] In post-industrial economies, in particular, the resource intensity of GDP is declining.

uncover policy options that pertain mainly to support the proliferation of these trends. These options emerge from a broader conception of climate mitigation than has typically been captured in the energy supply and demand technologies represented in existing energy–economic models. Each option has the potential to reduce GHG emissions, but each needs to be carefully evaluated in terms of its impacts on economic, social, and biological systems. Moreover, each of these options needs to be evaluated alongside conventional energy supply and demand alternatives in terms of their impacts. Expanding the analysis of the set of available options in this way should make us better off, as some of the new options will be attractive upon further analysis, although others will not.

1.4.2.1 Eco-intelligent Production Systems

Many authors argue that progress in developed countries has been driven largely by the technologically based substitution of natural resources for labour. As a result, labour productivity has generally grown faster than resource productivity. Against the background of environmental scarcities, though, this pattern has and will continue to change so that innovation may increasingly be shifted away from labour-saving advances towards resource-saving technologies.

Possibilities include:

- Eco-efficient innovation, that is making products in ways that minimize resource content, utilize biodegradable materials, extend durability, and save inputs during use (Stahel, 1994; Fussler, 1996; Weaver *et al*., 2000).
- Industrial ecology, that is moving from the nineteenth century concept of a linear throughput growth–in which materials flow through the economy as if through a straight pipe–to a closed loop economy in which industrial materials are fed back into the production cycle (Graedel *et al*., 1995; LTI-Research Group, 1998; Pauli, 1998).
- Products to services, that is shifting the entrepreneurial focus from the sale of hardware to the direct sale of the services through leasing or renting to facilitate the full utilization of hardware, including maintenance and recycling (Deutscher Bundestag, 1995; Hennicke and Seifried, 1996; Hawken *et al*., 1999).[25]
- Eco-efficient consumption, that is changing patterns of consumption (using new technologies) to achieve greater efficiency and to reduce waste and pollution (OECD, 1998) in sectors such as transport, food, and housing. Dematerializing consumption may go hand-in-hand with a shift from resource-intensive goods to service-intensive and knowledge-intensive goods (UNDP, 1998, p. 91).

[25] Most of this literature contains assessments of the economic potential of single technologies as well. For some more detail, see Chapter 3 of this report.

1.4.2.2 Resource-light Infrastructures

In a complementary strand of literature attention has focused on the greater scope for a transition in developing countries by decoupling investment from resource depletion and the destruction of ecological processes. More specifically, since the physical infrastructure in developing countries is still being designed and installed, they have a better opportunity to avoid the resource-intensive trajectories of infrastructural evolution adopted by developed countries (Shukla *et al*., 1998, p. 53; Goldemberg, 1998a). Specific examples cited in this context are efficient rail systems, decentralized energy production, public transport, grey-water sewage systems, surface irrigation systems, regionalized food systems, and dense urban settlement clusters. These can set a country on the road towards cleaner, less costly, more equitable, and less emission-intensive development patterns. The costs of such a transition are probably higher in places where considerable capital investments in infrastructures have already been made and where turnover is rather slow. For this reason, the timing of such choices is vital, as decisions about systemic technological solutions tend to lock economies onto a path with a specific resource and emission intensity.

In the context of climate policies, innovations in energy systems are of particular importance. Possible strategies advanced in the literature include a shift from expanding conventional energy supply towards emphasizing energy services through a combination of end-use efficiency, increased use of renewables, and new-generation fossil-fuel technologies (Reddy *et al*., 1997, p. 131). Developing countries that take advantage of these sorts of innovations could follow a path that leads directly to less energy-intensive development patterns in the long run and thereby avoid large increases in energy and/or GDP intensities in the short and medium term.

In many places, renewable energy technologies seem to offer some of the best prospects for providing needed energy services while addressing the multiple challenges of sustainable development, including air pollution, mining, transport, and energy security. For instance, 76% of Africa's population relies on wood for its basic fuel needs; but research and policy design targetted to improve sustainability has been largely absent. Solar energy has a significant potential in sahelian Africa, but slow technological progress, high unit costs, and the absence of technology transfer have retarded its installation. The Brazilian ethanol programme to provide automotive fuel from renewable resources (see *Box 1.4)* is another example. Throughout the developing world the exploitation of hydro potential also remains constrained because of high capital requirements and environmental and social concerns generated by inappropriate dam building.

1.4.2.3 "Appropriate" Technologies

Development of so-called appropriate technologies could lead to environmental protection and economic security in develop-

Box 1.4. The Brazilian Ethanol Programme

In 1974, Brazil launched a programme to shift to sugarcane alcohol (ethanol) as an automotive fuel, initially as an additive to gasoline in a proportion of about 20%. After 1979, pure alcohol-fuelled cars were produced, with the necessary technological adaptation of engines, through an agreement between the government and multinational car companies in Brazil. The conversion was driven primarily by tax policy and the regulation of fuel and vehicles. The relative prices of alcohol and gasoline were adjusted through Petrobras, the state owned oil company. In 1981 the price of alcohol was set 26% below that of gasoline, although gasoline's production cost was lower than that of alcohol (Pinguelli Rosa *et al*., 1998).

The alcohol programme created more than 500,000 jobs in rural areas and allowed Brazil to reduce oil imports. The sales of new alcohol-powered cars grew to 30% in 1980 and to more than 90% of the total car sales after 1983 until 1987. Alcohol accounted for about 50% of car fuel consumption at that time. However, the sharp decline in world oil prices along with deregulation in the energy sector meant the abandonment of alcohol-fuelled cars. Even in 1995, though, avoided emissions through alcohol fuel use in Brazil were 24.3MtCO_2. The cumulative avoided emissions from 1975 to 1998 can be calculated as 385MtCO_2 (Pinguelli Rosa and Ribiero, 1998).

ing countries. The label "appropriate technologies" is used because they build upon the indigenous knowledge and capabilities of local communities; produce locally needed materials, use natural resources in a sustainable fashion, and help to regenerate the natural resource base. They may enable developing countries to keep an acceptable environmental quality within a controlled cost (Hou, 1988). Low-cost, but resource-efficient technologies are of particular importance for the rural and urban poor (see *Box 1.5*). There is a latent demand for low-cost housing, small hydropower units, low-input organic agriculture, local non-grid power stations, and biomass-based small industries. Sustainable agriculture can benefit both the environment and food production. Biomass-based energy plants could produce electricity from local waste materials in an efficient, low-cost, and carbon-free manner. Each of these options needs to be evaluated alongside conventional energy supply and demand alternatives (see Chapter 3) in terms of the impacts and contribution to sustainable development. Expanding the analysis of the set of available options in this way should make us better off, as some of the new options will be attractive upon further analysis, although others will not.

It is important, in light of these examples, to realize that the results of greater resource efficiency differ according to the performance level of the technology under consideration. Technologies devised for high eco-efficiency and intermediate performance levels consume, for example, lower absolute amounts of resources than comparable technologies designed for high eco-efficiency and high performance levels. By design, performance levels can vary in such dimensions as level of power, speed, availability of service, yield, and labour intensity. Indeed, intermediate performance levels are often desirable because of their higher employment impact, lower investment costs, local adaptability, and potential for decentralization. For this reason, technologies that combine high eco-efficiency with appropriate performance levels hold an enormous potential for improving people's living conditions while containing the use of natural resources and GHG emissions.

1.4.2.4 Full Cost Pricing

Changing macroeconomic frameworks is often considered indispensable, in both developed and developing countries (Stavins and Whitehead, 1997), to bringing economic rationality progressively in line with ecological rationality. Economic restructuring and energy-pricing reforms both compliment and are a prerequisite for the success of many environmental policies (Bates *et al*., 1994; TERI, 1995). As long as natural resources, including energy, are undervalued relative to labour, the tendency should be to substitute the cheaper factor for the more expensive one. Giving a boost to efficiency markets requires, first of all, the elimination of environmentally counterproductive subsidies (at least over the medium-to-long

Box 1.5. Resource-efficient Construction in India

Recent analysis shows construction-sector activities to be major drivers of Indian GHG emissions. In addition, conventional building costs place traditional construction beyond the means of an increasing fraction of rural families. A new building technology developed by an Indian non-profit organization, Development Alternatives, reverses this trend. This technology uses hand-powered rams to shape compressed earth into strong, durable, weather-resistant but unbaked bricks. The ingredients for the bricks include only locally available materials, mostly soil and water.

Building new residential and commercial structures with these rammed-earth bricks creates rural jobs and delivers structurally sound buildings with high thermal integrity and few embodied emissions of GHGs. As a result of their inherently high thermal mass, these new buildings easily incorporate passive solar design for heating and cooling. Since they use little purchased input besides human labour, their cost is well within the range of poor families.

term), as on fossil fuels, motorized transport, or pesticides, as much as concessions for logging and water extraction (Roodman, 1996; Larraìn *et al*., 1999). Reform of environmentally destructive incentives would remove a major source of price distortions. Finally, shifting the tax base gradually from labour to natural resources in a revenue-neutral manner could begin to rectify the imbalance in market prices (European Environment Agency, 1996; Hammond *et al*., 1997). A more extensive discussion of eco-taxation, reporting a wide-ranging debate, is given in Chapter 6 of this report.

1.4.3 Decoupling Wellbeing from Production

Creating an improved, or at least a different, way of life supported by a given set of natural inputs could also enhance the overall resource productivity in society. For developed countries (and the corresponding social sections in developing countries) pursuing such an objective might start from the insight offered by some research that there is no clear link between level of GNP and quality of life (or satisfaction) beyond certain thresholds. Linton (1998) and UNDP (1998) draw this distinction clearly. Both sources argue that the quality of life is determined by subjective and non-subjective variables. On the subjective side, quality of life depends upon personal satisfaction, which in part depends on shared preferences and institutional values. On the non-subjective side, it depends upon opportunity structures, which may include access to nature, participation in community, availability of non-market goods, or public wealth, in addition to purchasing power. This literature describes situations in which GNP growth continues without a corresponding increase in human welfare as "overdevelopment" or "uneconomic growth" (Daly, 1997). For developing countries, however, the research suggests that this decoupling perspective may start from the insight that non-monetary assets (in terms of natural resources, just as in terms of community networks) need to be protected and enhanced to improve the livelihoods of the poorer and less powerful sections of society. Structures, patterns, and rates of economic growth may have to be shaped in such a way that these non-monetary assets are not diminished, but increased.

On both monetary and non-monetary accounts, a decoupling transition to sustainability implies a twin-track strategy. It may be achieved through both an intelligent reinvention of means ("efficiency") and a prudent moderation of ends ("sufficiency"; Meadows *et al*., 1992; Sachs *et al*., 1998) for the sake of both environmental and social sustainability. With regard to the environment, efficiency-centred strategies can have a limit; they can fail to account for the effects of continuing growth (Ayres, 1998). For instance, higher per-unit fuel efficiency of cars may not reduce total gasoline consumption in the long run if growth effects in terms of number, power, and size of cars cancel efficiency gains (see Chapter 3; Pinguelli Rosa and Tolmasquin, 1993).[26] With regard to social justice, resource consumption on the part of the rich has been shown, at times, to undermine the environmental sources of livelihood for the poor. Frequently discussed examples are the construction of large dams for urban electricity supply, which displace large numbers of subsistence peasants, or deforestation for industrial purposes, which marginalizes indigenous people living in and from the forest. In contrast to literature that postulates a "trickling-down effect" in the long term, this school of thought is concerned about the social cost in the present. For its proponents, to secure the rights of the most vulnerable would, in many cases, imply moderation of resource extraction in terms of absolute volumes (Gadgil and Guha, 1995). In the light of these reasons, social and technological systems that combine both high eco-efficiency and intermediate performance levels may be the most likely to foster human welfare at a lower cost to the environment and to social justice.

Four dimensions–intermediate performance levels, regionalization, "appropriate" lifestyles, and community resource rights–can be distinguished in the relevant literature. Policy options identified along these four dimensions emerge from a broader concept of climate mitigation than is typically captured in the energy supply and demand technologies represented in existing energy–economic models. Each option has great potential to reduce GHG emissions, but each needs to be evaluated carefully in terms of its impacts on economic, social, and biological systems. This sort of evaluation of opportunity cost has not, however, been reported in the literature under review. Moreover, most authors are ready to admit that the conditions of public acceptance of such options are not often present at the requisite large scale; they emphasize, however, the necessity to explore these options in order to foster long-term social learning processes. Regional views on the need for or feasibility of decoupling wellbeing from production vary widely. This subsection closes with a brief review of each dimension noted here.

1.4.3.1 Intermediate Performance Levels

Most of the literature on resource-efficient technologies takes for granted that performance levels will (and should) increase. For the sake of a broader portfolio of options, however, some analysts question this assumption. It is suggested that to create resource-light economies could imply deliberately designing technologies (e.g., in construction, ventilation, refrigeration, vehicles, crop cultivation, energy delivery systems) with levels of performance that lie below the maximum feasible. These technologies are often more labour intensive. For instance, the higher speed in transportation are (efficiency gains notwithstanding) unlikely to be environmentally sustainable in the long run; moreover, it is doubtful that this trend really enhances the quality of life (Hirsch, 1976; Wachtel, 1994). Designing cars and trains with lower top speeds could give rise to a new generation of moderately motorized vehicles with much lower resource requirements. In general, renewable energy sources and locally adapted materials, it is argued, become more com-

[26] For a more detailed discussion of the so-called rebound effect, see the special issue of *Energy Policy*, 28 (2000), 355–495.

petitive when the performance expectations on the demand side are reduced (Meyer-Abich, 1997). Sails still drive much of ship traffic in parts of the world, as on the Niger and Nile, or the great rivers of China. And bicycles carry a substantial portion of traffic in many regions of the world. Indeed, biomass of all kinds (wood for construction and fuel, plant and animal food and fibre, medicines, dyes, etc.) has been the renewable resource base for humankind since time immemorial. However, to successfully upgrade non-carbon-based technologies, the performance level desired seems to be a critical factor for them to be technically and economically viable.

1.4.3.2 Regionalization

Production and lifestyles based on high volumes of long-distance transportation carry a relatively high load of energy and raw materials. Some researchers argue (Shuman, 1998; Magnaghi, 2000) that a low-input society may require that the economy evolves in a plurality of spaces, in which markets that work with "regional sourcing" and "regional marketing" can co-exist with markets that focus on "global sourcing" and "global marketing". Avoiding demand for transport rather than just optimizing the modal split between private and public means of transport is often considered the objective of sustainable policies (Whitelegg, 1993), and regionalized economies may be best suited to this objective. Moreover, solar power, which relies on the widespread but diffuse resource of sunlight, may be best developed when many operators harvest small amounts of energy, transforming and consuming the resource at close distance. A similar logic holds for biomass-centred technologies. Plant matter is widespread, available, and heavy in weight; it may be best obtained and processed in a decentralized fashion. For this reason, some analysts argue that a resource-light economy has to be, in part, a regionalized economy. On the other hand, Chapter 2 points out that regionalization may impede technology transfer, leading to higher emissions, other things being equal.

1.4.3.3 "Appropriate" Lifestyles

Many authors question whether the accumulation of individually owned goods beyond a certain threshold continues to increase wellbeing at the same rate. They suggest that individuals and families could be capable of enhancing their personal resource productivity–a goal which, in turn, could be defined as the ability to maintain and/or increase satisfaction with lower and/or intermediate input of resources. Some authors consider intervention in the prevailing narrative of consumption–"more (consumption) is better"–a possible strategy to interrupt the satisfaction–consumption cycle (Common, 1995; Lichtenberg, 1996; Schor, 1998). These approaches draw their motivation from the hypothesis that, ecologically, it is not only the pattern, but also the overall scale of consumption that matters. If this is correct, then social capital in its broadest sense might have to substitute for increased absolute volumes of consumption (Robinson and Herbert, 2000). Chapters 5 and 10 elaborate on the role of lifestyles as a barrier to climate change mitigation, but also as a potential opportunity.

On one level, most resource-intensive consumer goods, in effect, used for only a fraction of time because they are individually owned. Intensity of use could be increased[27] through schemes that involve co-ownership, renting, or leasing (Zukunftskommission, 1998). On another level, the marginal utility of more free time increases faster than the marginal utility of more purchasing power for the more affluent parts of society (Schor, 1998). Choosing more wealth in time rather than more wealth in goods and services can be seen as a viable option, which promises to increase freedom while containing consumption levels. Finally, under conditions of "reflexive modernization" (Beck, 1991), consumption styles might emerge that put more emphasis on quality and non-material satisfaction rather than on rising volumes of consumption (Durning, 1992). As consumption activities become reinserted into the broader contexts of human wellbeing, diverse balances may be found between satisfaction derived from the marketplace and satisfaction derived from non-monetary assets (Reisch and Scherhorn, 1999).

1.4.3.4 Community Resource Rights

One-third of mankind derives its sustenance directly from nature (UNDP, 1998, p. 80); and these people live, for the most part, in ecologically fragile areas. Environmental resources are valued as a source of livelihood by groups as diverse as the fisherfolk of Kerala, the forest dwellers of the Amazon, the herders of Tanzania, and the peasants of Mexico (Ghai and Vivian, 1992). In such cases, households rely on non-market goods and natural habitats for important inputs into the production system (Cavendish, 1996). Many of these communities, over the centuries, developed complex and ingenious systems of institutions and rules to regulate ownership and use of natural resources in such a way that an equilibrium between resource extraction and resource preservation could be achieved. However, particularly under the pressure of the resource needs brought forth by individuals with relatively high energy consumption, the basis of their livelihood has been undermined, degrading their dignity and sending many of them into misery (Kates, 2000). Under these circumstances, sustainable development may mean, in the first place, ensuring the rights of communities over their own resources. Properly arranged, and in concert with competitive markets and astute institutional arrangements, resource rights could make investment consistent with community values and associated positive effects on climate change mitigation. Use of ecologically sustainable resources can be made a matter of self-interest. Well-designed resource-right mechanisms permit resource users to use new information and new technology and pursue new market opportunities. Resource use by outsiders becomes a matter of negotiation or trading on more equal terms, which protects the economic security of the communities involved. Better

[27] This would lower the demand for capital equipment and allow larger scale more efficient equipment to be used, which in turn would lower resource use and GHG emissions.

access to resources could offer new opportunities to increase the productivity of all components of the village ecosystem–from grazing and forestlands to croplands, water systems, and animals. This may, in turn, enhance people's well-being, which in these circumstances depends on increasing and regenerating biomass in an equitable and sustainable manner. It is well known from the economics literature that the management of common property resources seems to work best when group members can draw on trust and reciprocity, have some autonomy to make their own rules, and perceive to gain benefits from their efforts (Ostrom *et al*., 2000).

To summarize, we have examined three different perspectives that approach climate change mitigation from different vantage points–cost-effectiveness, equity, and sustainability–but converge in terms of the comprehensive set of goals to be pursued. However, the three perspectives use different analytical tools and causal relationships, and often provide different policy guidance. The main message of this chapter is that these three perspectives are complementary in nature, and can be helpful for the policymaker if used in conjunction. However, this does raise the issue of how to choose between various policy options and how to prioritize actions in the face of possibly divergent advice.

1.5 Integrating Across the Essential Domains–Cost-effectiveness, Equity, and Sustainability

To include issues of cost-effectiveness, distribution (narrowly defined), equity (more broadly defined), and sustainability adds enormous complexity to discussions on the problem of how nations can respond best to the threat of climate change. Indeed, recognition that these multiple domains are relevant complicates the task assigned to policymakers and international negotiators by opening their deliberations to issues that lie beyond the boundaries of the climate change problem, per se. Their recognition thereby underscores the need to integrate scientific thought across a wide range of new policy-relevant contexts, but not simply because of some abstract academic or narrow parochial interest advanced by a small set of researchers or nations. Cost-effectiveness, equity, and sustainability have all been identified as critical issues by the crafters of the UNFCCC, and they are an integral part of the charge given to the drafters of TAR. Integration across the domains of cost-effectiveness, equity, and sustainability is therefore profoundly relevant to policy deliberations according to the letter as well as the spirit of the Framework Convention itself.

One important preliminary step towards integration of the three perspectives that is developed in the body of this report is the use of ancillary and co-benefits, developed and assessed most fully in Chapters 7 and 8 and referred to in many of the other chapters, that could be used to augment mitigation cost estimates produced by the cost-effectiveness approach. Thus, one could add or subtract an estimate of the equivalent cost or benefits on various equity or sustainability metrics (e.g., changes in the extent of poverty, human capital development, etc.) that would result from specific mitigation policies. Although this would be a start on a more integrated quantitative assessment of costs, it would initiate a debate on how these other metrics ought to be evaluated and aggregated. This may make it desirable to move to a broader integrating framework where multiple policies could be evaluated according to multiple metrics simultaneously. The development of the concept of "mitigative capacity" is one new, but promising, step towards the development of the systematic evaluation of mitigation options from an integrated cost-effectiveness, equity, sustainability perspective.

Yohe (2001, in press) has recently introduced mitigative capacity as an organizing tool to aid policymakers and analysts alike as they try to accomplish this integration. Briefly defined, a nation's mitigative capacity reflects its ability to diminish the intensity of the natural (and other) stresses to which it might be exposed. The list of stresses for any particular nation might include climate change and climate variability, of course. It follows that to review the diversity of the determinants of mitigative capacity from a climate perspective can help assessors who contribute to IPCC Assessments and researchers who will look to their report for guidance in setting their research agendas. These determinants can, in short, provide a framework upon which to build and through which to assess systematic and comparable representations of nations' relative capacities to cope. Mitigative capacity is therefore offered here as one means with which to integrate and to evaluate the complex issues that have emerged since the publication of SAR. There may be other means to the same end, of course, but a focus on mitigative capacity has the virtue of concentrating attention directly on the problem at hand–climate change mitigation.

1.5.1 Mitigative Capacity–A Tool for Integration

There are eight distinct but related determinants of mitigative capacity (Yohe, 2001, in press). Cast here in the context of a single country trying to confront its climate change mitigation challenge, they are:

- range of viable technological options for reducing emissions;
- range of viable policy instruments with which the country might effect the adoption of these options;
- structure of critical institutions and the derivative allocation of decision-making authority;
- availability and distribution of resources required to underwrite their adoption and the associated, broadly defined opportunity cost of devoting those resources to mitigation;
- stock of human capital, including education and personal security;
- stock of social capital, including the definition of property rights;
- country's access to risk-spreading processes (e.g., insurance, options and futures markets, etc.); and

- ability of decision makers to manage information, the processes by which these decision makers determine which information is credible, and the credibility of the decision makers themselves.

This section will use these determinants as organizing tools in its assessment of the degree to which current thinking, as evidenced by subsequent chapters, includes the first very preliminary steps toward a thorough integration of cost-effectiveness, equity, and sustainability on the mitigation side of the climate problem.

Mitigative capacity is the mitigation analogue of the concept of adaptive capacity introduced in Chapter 18 of the WGII report (IPCC, 2001). Indeed, adaptive capacity is offered there as a framework upon which to build systematic and comparable representations of communities' and/or countries' ability to ameliorate or exploit the impacts of the natural or social stresses that they might face. As such, adaptive capacity plays a similar organizational role for WGII in their assessment of impacts as mitigative capacity does herein. WGII authors built their assessments around the notion that a system's vulnerability to climate change is determined both by its exposure to the impacts of climate change and by its adaptive capacity. Their analysis uncovered a list of determinants for adaptive capacity that is nearly identical to the list of determinants for mitigative capacity given above. Organization of their thoughts around those determinants enabled them to integrate cost-effectiveness, equity, and sustainability into their assessments of the relative vulnerabilities of different nations, regions, and sectors.

Many of the subsequent chapters presented here offer insight into the role of the first two determinants listed above in determining the ability of various nations to mitigate climate change. Section 1.5.1.1 offers a brief introduction to these insights. An equally brief assessment of some of the related literature from which the roles of the other determinants has been gleaned is given in Section 1.5.1.2. Its coverage is more suggestive of where climate researchers and policymakers should look for aid in formulating the next round of questions; it is less indicative of where past efforts and discussion have been concentrated.

1.5.1.1 Integrating Environmental, Social, and Economic Objectives in the Third Assessment Report

Chapters 3 and 4 herein discuss in detail the standard technological options to mitigate climate change. Some or all of these options might be available to any country as it decides to reduce or to slow its emissions of greenhouse cases. However, each technological option must be evaluated in terms of five factors:

- its technological potential in an uncertain environment;
- its economic potential given economic uncertainty and risk;
- existence of technical and economic constraints to its adoption;
- existence of social, cultural, and political constraints to its adoption; and
- ability of key decision makers to understand and to access its potential.

Chapter 5 underlines the significance of each of these characteristics. It points out that cost and performance specifications are critical; however, a technology could be expensive in one place and relatively inexpensive in another; or it may be inexpensive when denominated in one numeraire, but expensive when denominated in another (see Schneider, 1999). Chapter 5 also highlights social and economic constraints derived from high private discount rates, market failures, closed economies, uneven allocations of resources, uneven access to decision-making processes, and other characteristics of social and cultural structures. Finally, Chapter 5 focuses considerable attention on information. Decision makers must be able to understand a technology's economic and technical potential in the context of their own countries, for which data and information may be scarce or, in cases where prices do not reflect social cost, misleading. Clearly, these observations extend the discussion beyond simply listing gadgets towards developing an understanding of how country-specific characteristics might enhance or impede decision makers' abilities to adopt mitigative technologies.

This chapter also underlines the sensitivity of acceptable policy instruments to a similar list of critical parameters that extend efficiency discussions to include equity and sustainability. These include:

- opportunity cost of their implementation, measured broadly to include their development, equity, and sustainability implications;
- sensitivity of these costs to alternative designs;
- availability of credible information and the ability to monitor critical factors in the face of uncertainty;
- definition of a wide range of policy objectives and the degree to which they complement the objective of climate mitigation;
- credibility of the policies and legitimacy of the policymakers;
- social, cultural, political, and economic constraints to their implementation, and
- the structure of the decision-making process itself.

These characteristics clearly have enormous significance when they are cast in the context of development, equity, and sustainability. Later chapters in this report show how alternative policy designs can, on average, have widely different costs and implications even if they achieve comparable results. Chapters 6 to 8 show, for example, that the cost of a policy does not depend on the specification of its targeted outcome only. It also depends on the specification of its timing, on the flexibility that it allows, and on the degree to which it is supported by the international co-ordination of similar efforts across the globe. Different policy designs for the same objective can also have different distributional impacts–different sets of winners and losers across space and time who all come to the table with different access to decision making. Moreover, the opportunity cost of any policy can be measured not only in terms of economic cost, but also in terms of non-economic metrics that measure progress or regression across a wide range of critical variables and against an equally large range of social, cultural, or political objectives (see Schneider, 1999). As a result, mitigation policies that have been successfully adopted in one country might be totally beyond the range of possibility in another.

Finally, differences in the flexibility of alternative policy designs can also mean differences in long-term sustainability from one country to another. Flexibility in response to one mitigation policy that adds efficiency and reduces costs in one place may threaten the very existence of critical systems in another. Ultimately, the goal of international agreements is to induce decision makers at various levels–national and municipal governments, corporate executives, rural communities, and individuals engaging in both production and consumption decisions–to undertake actions that lead to the mitigation of GHGs. There is, in short, a multitude of policy options and instruments available to decision makers at various levels.

Figure 1.7 illustrates this complexity in a diagrammatic form by taking the example of the Kyoto Protocol. The parties have agreed to a 5.2% reduction of Annex I emissions below 1990 levels by the first commitment period, 2008 to 2012. To realize these reductions, however, national governments in these countries have to undertake policy measures that induce corporate and other actors to modify their behaviour. As is shown presently, these policy decisions cover both regulatory and market instruments. Individual economic actors will respond to these incentives through internal changes as well as domestic and international decisions. International decisions cover the innovative Kyoto mechanisms (JI, IET, and the CDM) and are relevant to non-Annex I countries, which will need to take supportive policy decisions as well. These are specifically in the area of institutional development, capacity building, project approval, project monitoring and certification, and national reporting.

Uncertainty, vulnerability to shocks, and attitudes towards risk influence the perceived legitimacy of various decision options. At a global or national level, public opinion and therefore public policy is affected by the scientific uncertainty over the range and impact of climate change. At subnational levels, such uncertainty and vulnerability lies not only in the future, but also in the present circumstances of specific groups–the poor, the communities living in fragile or threatened areas, and the ecological refugees (Gadgil and Guha, 1995). It shapes the collective experience of such groups, determines their decision objectives, and affects their choices as well as susceptibility to policy-induced changes.

Finally, the incentive situation, the nature and strength of institutions for collective action, and the quality and type of information available to decision makers affect individual decisions. All three of these factors vary from one context to another and from one level of decision making to another. Next the nature of governmental policy intervention is discussed, and then the context within which such policies are used is analyzed.

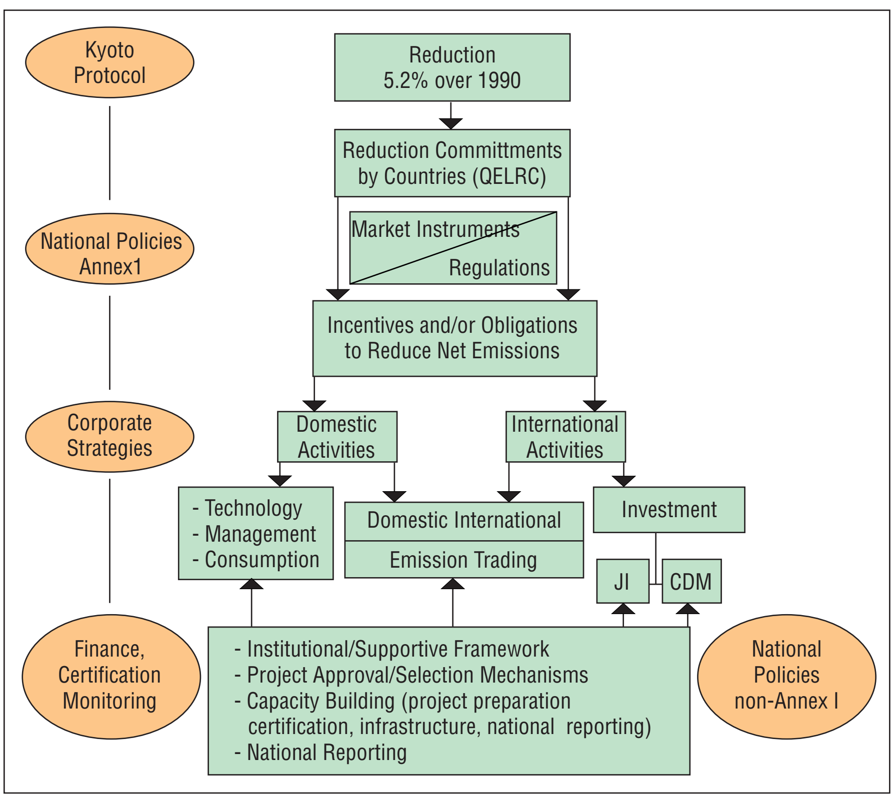

Figure 1.7: *Levels of decision making for Kyoto mechanisms.*

1.5.1.2 Expanding the Scope of Integration

Decisions that lead to the emissions of GHGs that result in global warming are made under, and generally because of, the system of incentives and institutions in place, and are based on the information available to decision makers. Influencing such decisions requires policy intervention at global, national, or local levels. Conversely, the existence of institutions and legitimacy determines the effectiveness of the menu of potential governmental policies outlined above. There is significant heterogeneity within most countries in the types of climate change impacts that might be expected and in the likely impact of GHG mitigation policies. The ability to adapt to climate change depends on the level of income and technology, as well as the capacity of the system of governance and existing institutions to cope with change. The ability to mitigate GHG emissions depends on industrial structure (the mix of industrial activities), social structure (including, e.g., the distance people must travel to work or to engage in recreational activities), the nature of governance (especially the effectiveness of government policy), and the availability and cost of alternatives. In short, what is feasible at the national level depends significantly on what can be done at the subnational, local, and various sectoral levels. However, most studies assume that the national level is the most appropriate for assessing and reacting to the externalities that result from emissions of GHGs and for negotiating international climate change agreements.

The prospect of climate change is just one of many issues of concern to governments, and in most countries climate policy is debated within a broader framework. National policymakers, therefore, have to make trade-offs in implementing climate policies within a comprehensive national and international political economy framework. Many political parties and stakeholder groups oppose climate policy because of perceived conflicts with private sector interests. They also perceive conflicts with traditional macroeconomic goals, like full employment, price stability, and international competitiveness. They also sometimes fear competition with other traditional objectives for public attention and public expenditure (e.g., health care, national security, infrastructure, and education). Likewise, some people may resist mitigation policies (regardless of who pays for them) because of the perceived adverse impacts on economic growth and poverty eradication, even though others might suggest that the implementation of such policies could provide potential opportunities for sustainable development.

Also, many countries have more than one national policy-making authority. In some cases, this diversity may reflect a separation of the executive and legislative branches of government. In others, it may simply be that separate agencies are responsible for economic policy, environment, and international affairs. These agencies will have different views regarding both the needs for climate policy and its likely impact on other goals. The decision-making process invariably reflects the relative political influence of these groups, and involves political negotiations and compromises between them. As a result, O'Riordan *et al*., 1998) argue that issues considered by governments to be on the policy periphery, like climate change, are not easily factored into consideration of issues at the policy core (such as health care, education, national economic policy, or corporate manufacturing strategy). The issue networks and policy communities around environmental ministries in most countries are weak relative to those around economic and defence ministries. Climate change is sometimes invoked to boost support for existing policy agendas, such as industrial restructuring. Nonetheless, climate change has seldom, if ever, been perceived within the powerful ministries and their policy communities as sufficiently threatening to their departmental interests to fundamentally change those agendas (O'Riordan and Jäger, 1996; Beuerman and Jäger, 1996).

There is, as well, enormous variety in the range of institutional and other conditions in various countries at the subnational level. The political decision-making process in developed countries is affected to a certain degree by powerful non-governmental institutions–including corporations and issue-based non-governmental organizations (NGOs; March and Rhodes, 1992; Sabatier and Jenkins-Smith, 1993; Smith, 1993; Michaelowa, 1998; O'Riordan *et al*., 1998). These can be a source of resources and new ideas to address climate change as it occurs, but they can also impede the identification and response to changes because of vested interests in the current or some desired allocation of resources. In developing countries, a growing number of institutions have emerged to champion environmental agendas. These range from groups concerned with narrowly defined problems and opportunities (e.g., grassroots groups, wetlands protection groups) to broad-based rights groups (e.g. women's groups) that address a range of common problems (see, e.g., Banuri *et al*., 1994). However, significant differences continue between the legitimacy and reach of such groups in the developed and developing regions.

The role of the informal sector can also differ between developed and developing countries (see, e.g., Cantor *et al*., 1992). Although the term is defined somewhat loosely in the literature–often referring to urban, small-scale, non-organized economic activities, and elsewhere to activities not covered in national tax nets–estimates suggest that the informal economy may cover as much as one-third of the economic activity of some developing countries. Given its relative imperviousness to analysis as well as policy influence (indeed, its very existence is credited by some writers to its ability to escape policy influence), it is difficult to project how this sector will react to impacts from climate change or mitigation policies.

The role of information depends critically on the legitimacy of institutions that provide it. The capacity for research, analysis, and policy development is generally weak in developing countries, and especially so in terms of climate change. More importantly, this limited capacity is focused exclusively at the national level. The result is often a credibility gap between the national and local levels. In general, it is difficult to convince local actors of the significance of climate change and the need for corrective action.

More importantly, the bulk of the research and analytical capacity at the global level is concentrated in the developed countries. This is true especially of climate modelling, but also in analyses of the relationship between climate change and sustainable development. Since the late 1980s, massive investment in climate change research has taken place in the developed countries. In contrast, there is a paucity of research institutions in developing countries, with a relatively small level of research effort and investment. This is adequate neither for policy development nor for reassuring policymakers and NGOs of the developing region that the research results are unbiased (Sagar, 1999).[28]

Taken together, these insights suggest a need for investment in the research and analytical capacity of the developing countries, and for orienting the research effort in both developing and developed countries towards the local impacts of climate change and the capacity for climate change adaptation and mitigation. Section 1.5.2 indicates how approaching this complexity within the organizing concept of mitigative capacity can help to generate insights into interpreting and extending analytical exercises, integrating these exercises across multiple stresses, and using this integration to inform discussions and debates in the policy arena.

1.5.2 Lessons from Integrated Analyses

Integrating, organizational tools are most useful when they also provide an effective means to assess the existing literature so that new hypotheses can be articulated and new directions can be identified.

One such lesson is that to aggregate representations of mitigation across nations and/or groups may be misleading. Quite simply, the capacity to reduce emissions of GHGs can vary dramatically from nation to nation, sector to sector, region to region, group to group, and timeframe to timeframe.

Secondly, one country can easily display high adaptive capacity and low mitigative capacity simultaneously (or visa versa), even though both capacities share the same list of determinants. In a wealthy nation the damages associated with climate change may focus on a small but well-connected group of people, while the cost of a wide range of adaptation options can, through a well established tax system, be distributed across the entire population. The same country might, however, include another small group of people who would be seriously hurt by most if not all of the wide range of available mitigation options and/or policies. The benefits of mitigation would meanwhile be marginal for most people because they would be distributed widely across the population and spread far into the future. Mitigative capacity could then be small.

Countries most vulnerable to climate change may have the smallest mitigative capacity. Vulnerability to climate change results from high exposure to climate impacts, low adaptive capacity, or both. In the high-exposure case, the opportunity cost, broadly defined, of expending resources to mitigate GHG emissions may be too high. In the case of low adaptive capacity, the factors responsible may also work to diminish mitigative capacity. And in the third case, both deleterious correlations could work to complement each other.

Enhancing any one component of mitigative capacity may (or may not) reduce the (marginal) cost of mitigation, because it either expands the set of possible mitigative options or because it reduces the constraints that stand in the way of their efficient application. Adding to the list of available technological options can, of course, lower the cost of implementing a specific policy designed to accomplish a specific objective, but the additions must be more socially acceptable than the existing alternatives, as well as structurally, socially, politically, and culturally feasible. If not, they will not be adopted. Furthermore, their informational requirements must not exceed the informational capacity of the host country.

A nation, region, or community's international position can play a significant role in determining its ability to exercise its mitigative capacity, because outside entities can influence the effectiveness of technological options and/or domestic policy alternatives. External forces can have a secondary but nonetheless significant effect on the likelihood that mitigation will occur. Section 1.2 highlights the value of international co-ordination. Trade policies, be they global or the domestic policies of significant trading partners, directly influence national incomes and their distribution. Trade also influences the degree to which a country's development plans put pressure on its stocks of social, human, and natural capital. Each of these factors subsequently affects the constraints that determine the set of feasible mitigation technologies and policies.

Developing indicators of mitigative capacity could help determine who should be expected to do what in terms of mitigation. Examining the determinants of mitigative capacity can identify weak points in the links required for countries to recognize and to act upon the need for climate mitigation This approach can organize existing information effectively as well as suggest new research directions. Specifically, attention to mitigative capacity underlines the role of instruments and targets in framing policy discussions. There are, typically, multiple targets (environmental improvement being one of them) and multiple instruments to achieve them. Contemplating the determinants of mitigative capacity suggests that there is a benefit from broadening the range of instruments used in climate policy. This may be especially so if "climate policy" is under-

[28] Participants in international research programme are mostly scientific experts and do not have expertise in development, equity, or sustainability issues.

stood to include mechanisms to achieve environmental goals, sustainability goals, equity goals, and development goals. In this light, mitigative capacity highlights the necessity to observe market failures, political failures, and other failures that might otherwise be overlooked. The fundamental questions are, then, ones of a broad perspective to see exactly how much public policy should be devoted to enhancing mitigative capacity in ways that can help answer questions like "Where are the payoffs clearly greater than the costs?" or "Where is the low-hanging fruit that deserves picking?"

Contemplating the complexity of mitigative capacity reveals that the sources of uncertainty in understanding mitigation extend far beyond the boundaries of the uncertainties that cloud how various technologies might be applied and how various policy designs might function. The same determinants of mitigative capacity that bring development, equity, and sustainability factors into play add to the list of these sources, just as they do on the impact side of the climate change calculus. In short, therefore, anticipating how mitigation might evolve, how much it might cost, how effective it might be, and how the costs and benefits might be distributed is just as uncertain as anticipating how systems might adapt to the impacts of climate change and climate variability.

Understanding the determinants of mitigative capacity offers a way of organizing not only the analysis of mitigation, but also the negotiations over how to meet the mitigation challenge. Indeed, enhancing mitigative capacity can be a policy objective in and of itself. The means by which this enhancement might be accomplished can be drawn directly from an understanding of how the determinants work within and across countries, how they might complement one another, and how they might conflict. Of course, the opportunity cost of enhancing mitigative capacity, measured in terms of cost of regressing against other objectives, is critical in evaluating its desirability. It is also clear, given the way in which its determinants can be expected to interact, that enhancing mitigative capacity means more than simply transferring resources from one nation to another. Weakness beyond access to adequate resources can surely impede the capacity to mitigate any stress; and so it follows that these weaknesses can undermine significantly the efficacy of offering or requesting simple financial support.

1.5.3 Mitigation Research: Current Lessons and Future Directions

Broadening the domain of analysis to include concerns of development, equity, and sustainability over multiple time scales adds enormous complexity to policy deliberations. A portfolio of strategies (not just policy instruments) that draw on efficiency and cost-effectiveness, equity, and sustainability considerations may nonetheless offer the promise of identifying new options and synergies that may make the job of implementing climate policy less disruptive to societies and economies. In particular, it may help to broaden the range of win–win options.

Concepts like mitigative capacity can help to clarify the trade-offs within and between this expanded range of options. It can show how the assessment of climate change mitigation opportunities contained in this volume can be used and integrated to confront the problem of climate change most effectively. This is especially true when the broad lessons from WGIII herein are taken in concert with lessons drawn from the assessment provided by WGII (IPCC, 2001) on impacts and adaptation. Many of the determinants of adaptive capacity are essentially the same as those of mitigative capacity. Therefore, a portfolio of policy strategies that enhances the capacity to mitigate most effectively should also be effective in enhancing the capacity to adapt. A number of lessons and directions for future research can be enumerated.

- *Improved deliberations on appropriate climate policies in the short, medium, and long terms.*

The literature being brought to bear on the climate issue increasingly shows that policies beyond simply reducing GHG emissions from a specified baseline at minimum costs can be extremely effective in abating the emission of GHGs. Consideration of policies not directly focused on climate, such as those focused on the broader objectives of sustainable development, gives policymakers more flexibility to achieve climate policy objectives.

- *Expanded lists of tools for decision makers and analysts.*

Consideration of the objectives of development, equity, and sustainability can help buy in more participants to climate policies–beyond national and international delegations to include state, local, community, and household agents, as well as NGOs. It also expands the list of tools that can be applied to illuminate the decision-makers' deliberations, from efficiency- and/or distribution-based analytical tools to include alternative decision-analytic frameworks and the development of alternative scenarios.

- *Weighing the costs and impacts of a broader set of policies according to a longer list of objectives.*

Climate deliberations would then consider the climate ramifications of policies designed primarily to address a wide range of issues, including development, equity, sustainability, and sustainable development, as well as the likely impacts of climate policies on the achievement of these other objectives. As part of this process the opportunity costs and impacts of each instrument are measured against the multiple criteria defined by these multiple objectives.

- *A portfolio approach to policy that effectively enhances the capacity to meet the mitigation challenge as well as the capacity to adapt to climate change.*

Focusing research and policy on the determinants of mitigative and adaptive capacity simultaneously can show when, where, and how synergies and conflicts between mitigation and adaptation might arise. Focusing research on these determinants also makes it clear that policy making in either sphere can be matched by complementary action in the other. Coping with the climate problem is not a question of mitigating and then adapting. Nor is it a question of adapting and then mitigating. It is a more holistic question of doing both at the same time; focusing attention on the common determinants of mitigative and adaptive capacities can lead productively to an understanding of exactly how to meet these coincident challenges.

- *Much additional research is needed before concepts like mitigative capacity can be used to assess the relative merits of specific options.*

Integrating concepts like mitigative capacity should prove useful as a heuristic device to integrate diverse policy instruments into a comprehensive policy portfolio, to discover the metrics with which costs and benefits should be measured, and (perhaps most immediately) to broaden the range of no regrets options.

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