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IPCC WGIII, Writing Team II - Drafts Chapter 6

Dear Ladies, Dear Sirs,

I am pleased to send you today copies of the outline for Chapter 6 as well as the drafts section 6.1 and 6.2 just received from Prof. G. Pillet for you. The following sections will be sent later.

Wishing you a very good (summer-)time I remain,

Very truly yours,

R. Schoch, secretariat
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*PS: Gernique Pillet suggested you may forward a copy
to Goldenberg / Stiglitz*



Decision Making Framework to Address Climate Change

IPCC WG III Writing Team II • Chapter 6

6.1 Decision Criteria



6.1.1 Criteria of Choice

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6.1 Decision Criteria

This section investigates some of the basics of decision making and gradually introduces the new ground broken by climate change.

It first presents the criteria of choice in relation to standard economic situations as well as with respect to decisions that are taken beyond individual choice-like situations. Then, it delimits choice variables like certainty, risk, uncertainty and ignorance, and catastrophic risk. Finally, it indicates the variations to the decision making scheme that climate change might lead to.

The next section is devoted to the factors that affect decision making (e.g., time, information, irreversibility, attitudes, and value) whether generally or with respect to environmental concerns.

6.1.1 Criteria of Choice

Main concepts underlying decision making are presented to familiarise the reader with the criteria for choice and standard decision approaches. Many questions arise.

What is choice? On which criteria do individuals make choices in economic contexts? Do choices with respect to environmental problems convincingly differ from choices in economic situations? Is the economic foundation supporting decision making enough robust to address climate change related decision problems? Finally, what are the decision rules we already have at hand to respond to risk, uncertainty, near ignorance, or catastrophic risks, and to which extent do we need to forge new rules and/or variations to old ones? For instance, this might be the case for insurance in the sharing of climate change associated risks.

Though economic requisites are not a priori in dispute, classical formulations of such criteria and variables in economics might no longer suffice because of the existence of some disturbing amount of unpredictability with regard not only to the accuracy of either climate changes or economic forecast, but also with regard to the natural (sea-level rise, ice-sheet melt, coastal erosion) and man-induced (enhanced greenhouse effect) sources of environmental variability, and thus to the evolution of nature-economy joint systems (Vercelli, 1991, Pillet, 1993, Chichilnisky, 1993, Tooley, 1994). It is therefore our ambition, initially, to stick to the current status of choices in economic situations, as we ordinarily understand that expression. And then to consider decision making situations to address climate changes. This will help us thinking and assembling the pieces the building of an adequate decision making framework presumes.

6.1.1.1 What is choice?

What do “economic situations” mean? On which criteria do we make choices in economic contexts?

The general picture of the *theory of choice* is as follows. The individual can take a limited range of actions that have attached consequences. He or she “has in mind an ordering of all possible consequences of actions”. Among the actions actually at hand, “that action is chosen whose consequences are preferred to those of any other available action” (Arrow, 1951).

Together with the relevant settings of some central conditions as well as of the criteria of choice, such situations constitute the reference framework in which economic choices apply.

Central conditions are, for example, a theory of market interactions and clearing as well as any coherent theory of reactions to the economic stimuli (prices, in essence). Assumptions also compose the economic framework. For instance, a decision-maker's beliefs can always be represented by a unique probability measure; economic agents are said to be perfectly competent to deal with the difficulty of the processes involved in the decisional situation. More radically, economic situations (and theory) are based on *rationality*, as a matter of principle.

On the “apparatus” side, economic criteria of choice rest upon representations and orderings of consequences of actions by means of the assumption of a *utility function*. A utility function renders intelligible with regard to observable situations the ability of the consumers to rank their preferences in a consistent order (in like manner, entrepreneurs will prefer more profit to less if each is equally risky). The assumption of a utility function, therefore, postulates a *consistency* of human choice—in short, *rationality*. From a decision analysis viewpoint, this postulate places the focus on the decision to reach, not on the process per se. Verily, inasmuch as individuals are assumed to be perfectly knowledgeable and rational, the most valuable option—in terms of utility, or human wishes—is always chosen (Price, 1993).

Yet, will *rationality* and attached economic criteria or choice still play the same pivotal role in climate change-oriented decision making processes as in economic situations? This might not constantly be the case. Decision makers must initially be aware of the following differences.

With respect to the climate change perspective, choices will be of collective and of longer-term view nature—they will no longer be individual and fixed choices (for instance, one cannot make the hypothesis that, in as far as global environmental concerns call for international agreements and actions, individual nations might act as individual economic agents do). Choices will not be made

with respect to a fixed set of alternatives, either. In addition, they will not be confined to market related decision situations, but will also be concerned with non-market related decision situations (including issues of ethics, equity, poverty, and fragility of natural ecosystems and species).

Last, introducing these specific factors into decision making problems along with key man-induced and natural sources of change will inevitably disclose uncertainties and risks that were not previously recognised. This will reveal less dependable probability distributions, lack of data and knowledge, stronger uncertainties, highly specific risks, irreversibilities, gaps between competence and difficulty (are agents able to figure out all of the complexities of a nature-economy system?), small contributions of information from a number of diverse sources, unpredictable situations, intertemporal perspectives, and scientific controversies.

In spite of these circumstances, economic choice situations and criteria constitute useful benchmarks for making decisions. Consider them in a practical way.

6.1.1.2 *Maximising something*

For the classicists, rationality had the (limited) meaning of preferring more to less (for instance, capitalists choose to invest in the industry yielding the highest rate of return, landlords rent their property to the highest bidder, and so on). Being rational merely meant making decision.

Today, economists do not assert that human agents are “rational” by definition. Rationality appears as a lawlike refutable statement which “simply means behaviour in accordance with some ordering of alternatives in terms of relative desirability” (Arrow, 1951, Blaug, 1992). In this respect, it designates a “maximisation of something” (Arrow, 1987); in other words the maximisation of the expected value of a given utility function (Savage, 1954). *Maximising something* is the basal economic criterion of choice (minimising chance of adverse effects belongs to the same criterion). Note that subjective arguments are compatible components of the assumption of a consistent utility-maximising behaviour and profit-maximising conduct.

Main economic choice criteria are utility-based ones (cf. Table 6.1). Other, “weaker” choice criteria are rights-based ones (see Table 6.2).

■ *Utility-based* criteria are prime choice criteria in economics. They mean maximising the expected utility. They entail decisions that are based on the valuation of outcomes—wealth levels, time streams of consumption, etc.—(Morgan and Henrion, 1990).

Table 6.1 – Examples of some utility-based decision criteria

Source: After Morgan and Henrion, 1990: 26

Benefit-cost: Estimate the benefits and costs of the alternatives in economic terms and choose the one with the highest net benefit.

Maximise multi-attribute utility: This is the most general form of utility based criterion. Rather than use monetary value as the evaluation measure, MAU involves specifying a utility function that evaluates outcomes in terms of all their important attributes (including uncertainties and risks). The alternative with maximum utility is selected.

Cost effectiveness: Select a desired performance level, perhaps on non economic grounds. Then choose the option that achieves the desired level at the lowest cost.

Minimise chance of worst possible outcome ... maximise chance of best possible outcome, etc.: Political and behavioural considerations frequently dictate the use of such criteria.

Maximum budget (bounded cost criterion): Set the maximum budget to devote to risk management activity.

Minimise maximum regrets: Choose measures of “regret” and minimise the maximum regret.

Minimax criterion for catastrophic risk: For each decision alternative find the loss associated with the extreme event. From among these losses find on with the maximum loss and try to minimise it. This a conservative criterion.

For example, they would involve a balancing of benefits and costs in a benefit-cost analysis framework (Table 6.1).

A more general formulation has been set up in terms of *maximising a multi-attribute utility function* (Table 6.1) for situations where options involve “collections of attributes that are incommensurate” (Keeney and Raiffa, 1976, Morgan and Henrion, 1990). The resulting decision models can thus avoid the dilemma of converting each attribute to an equivalent monetary value.

Variations to utility-based decision criteria are available. A *cost effectiveness* criterion (Table 6.1) can be used where the value of benefits cannot be estimated—but a choice must be made between alternatives (Morgan and Henrion, 1990). A *maximum budget* can be set to devote to risk management activity (bounded cost criterion). Finally, measures of “regret” can be chosen and the maximum regrets minimised (Table 6.1).

Economic criteria of choice don't have to be maximisation-related, utility-based criteria definitely. For instance, addressing climate change might mean international and intertemporal cost sharing, common but differentiated responsibilities, self-constrained risks, North-South financial transfers, specific commitments, and so on.

Table 6.2—Examples of some rights-based criteria

Source: Morgan and Henrion, 1990: 26

Zero risk: Independent of the benefits and costs, and of how big the risks are, eliminate the risks, or do not allow their introduction.

Bounded or constrained risk: Independent of the costs and benefits, constrain the level of risk so that it does not exceed a specific level or, more generally, so that it meets a set of specified criteria.

Approval/compensation: Allow risks to be imposed only on people who have voluntarily given consent, perhaps after compensation.

Approved process: Not strictly a decision criterion for analysis, but widely applied in risk management decision making. If all relevant parties observe a specified set of procedures (e.g., under some international convention), then any decision reached will by definition be acceptable.

Other criteria can be postulated, as for example equity, a satisfying strategy (Simon, 1987), ecological sustainability rules, minimum surprise. Outcomes can also be applicable to changes in natural ecosystems. And regional distribution can be at issue.

■ *Rights-based criteria* (Table 6.2) have been thought to deal with processes and constrained actions or activities (Morgan and Henrion, 1990).

As Morgan and Henrion argue, some of these criteria are not adequate to deal with exogenous, naturally occurring risks as for instance the *zero risk* criterion which simply does not allow the introduction of the risk. Nevertheless, this criterion and the like are appropriate with respect to “new” human risks, including climate change associated risks once these can be understood as endogenous occurrences. For instance, the *approved process* criterion insists “that all the relevant parties observe a specified set of procedures” such as some internationally signed convention defining a due process.

But don't let's look too far ahead. To the point, let's recall that standard economic choice criteria are supported under restrictive assumptions such as perfect rationality, information and knowledge, finite time horizon, etc.

6.1.1.3 *Bounded rationality*

As already explained, rational behaviour is a “first approximation” to actual behaviour. For instance, as soon as one faces either imperfect forms of competition or non-market resources allocation decisions, the knowledge requirements radically shift and are prompt to exceed those usually required for the price system. It is, therefore, accepted that (economic) rationality hypotheses be supplemented by

assumptions of a different character (e.g., information-gathering ability and limitation of both knowledge and computational capacity). It is accepted that rationality, obviously, is bounded (Simon, 1957, Arrow, 1987). Basically, these cognitive difficulties are connected to decisions that lie far away from individual-related, standard economic situations; they are relative for example to decisions that must be reached through international conventions, or to decisions that, *independently of the valuation of the outcomes*, are destined to eliminate risks.

As a concept, “bounded rationality” has been coined to name rational choice that takes into account the “cognitive limitations of the decision-maker” (Simon, 1987). This makes bounded rationality much more concerned with *the ways in which the actual decision-making process influences the decisions that are reached* than with reaching decisions assuming the maximisation of something, as we are used to consider from a standard economic viewpoint. This concept designates a different type of rationality, namely procedural rationality. Incidentally, a decision which optimises the expected value of utility will possibly be in opposition with a decision which optimises cooperation because the former places the focus on *the decision to reach* while the latter puts the emphasis on *the decision process in itself*.

6.1.1.4 Procedural kind of rationality

The former cognitive limitations may break usual limits on specific information. In the words of Simon, they are almost always limits on the adequacy of the scientific theories that can be used to predict the relevant phenomena (Simon, 1987). Meteorology and atmospheric chemistry, on the one hand, as well as economics, on the other hand, openly leave large bands of uncertainty in reference to climate change. In addition, lack of knowledge about fundamental mechanisms that equations cannot currently master represents limits to computer models in both domains.

These difficulties typically occur with respect to decisions that are taken on a national or international scale when governments negotiate some form of agreement and countries differ in their economic wealth, reliance on fossil fuels, endowment of alternative resources and technical capabilities. For instance, the need for an equitable distribution of tasks both at the national and international levels is the cornerstone of the 1992 Framework Convention on Climate Change (FCCC). While all the Parties are required to contribute to the collective effort by elaborating a national programme, the application of the principle of “common but differentiated responsibilities” implies

1 that the industrialised nations must assume the prime share of the effort—first by adopting specific
2 national measures to stabilise greenhouse gas emissions, second by promoting the transfer of financial
3 resources, know-how and/or technologies to developing countries, in particular the least developed
4 countries (FCCC, 1992, BUWAL, 1994).

5 Specifically, “procedural” rationality designates the rationality of a decision in terms of the
6 manner in which it is made while economic—also called “substantive”—rationality names the
7 rationality of a decision considered independently of the manner in which it is made (in the case for
8 substantive rationality, rationality evaluation refers exclusively to the results of the choice, not to the
9 decision-making process in itself—Faucheux and Froger, 1994).

10 *Which kind of theory can better predict and explain the decisions at issue? Shall we place interest*
11 *in the decisions to be reached only, or shall we focus attention on the (international) decision-making*
12 *process as such?* Answering to these questions and the like would *command the choice* between
13 substantive and procedural rationality frameworks (Simon, 1987). From an economic standpoint,
14 unfortunately, the fact that the manner in which the decision is made—and not the result of the
15 choice—is at issue in the decision evaluation makes the procedural kind of rationality mostly
16 undetermined. Reasonably, procedural rationality can be at work for setting norms or institutional
17 arrangements as a framework for further economic choices.

18 Since the *Framework Convention on Climate Change* (FCCC) came into force in March, 1994,
19 further choices vis-à-vis climate change are supposed to be economically sounded choices.

20 6.1.1.5 *Accommodating the added uncertainty attached to climate change*

21 The cognitive and computational limitations that have been pointed out by the concept of bounded
22 rationality make sense with respect to climate change concerns. Economic-oriented decision making
23 is also concerned with these limitations. Accordingly, devices exist that can help to some extent at
24 solving predictions where new information is needed to reduce uncertainties.

25 Climate change prospects also reveal—besides cognitive limits—that data one should use to make
26 long term decisions “is weaker than we had imagined when climate change was overlooked or
27 disregarded”. Ignoring climate change would simplify decision making, but it would be irrational to
28 return to our previous lower level of uncertainty awareness. We thus have to accommodate the added
29 uncertainty attached to possible changes in climate (Caselton and Luo, 1994) and to make decisions.

As a consequence of insufficient knowledge and data, predictions of the rate and extent and timing of climate change and their effects have been made in terms of scenarios rather than in usual statistical terms. In particular, this situation reflects a gap between the information that is available on climatic processes and the one that would be relevant to statistical prediction—and consequently to the standard economic, namely “Bayesian”, framework—and that is in short supply at present time.

What is at stake? Within the economic rationality framework, decisions are based on the valuation of outcomes and/or of alternatives. The valuation procedure focuses on a *quantity* that is known as a “state of nature”. Standard decision making is served by the Bayesian statistical approach which represents any information or knowledge concerning this state of nature by assigning *probabilities*. In this respect, the representation of information in the form of conventional, necessarily precise, probability distributions has been developed in the statistical literature for well over 100 years.

In view of the climate change concerns, and lack of knowledge and data, we undoubtedly have to address decision situations under “strong uncertainty” and even “near ignorance” in addition to those concerned with conventional levels of uncertainty or risk (see Table 6.3). How to treat information sources (these are diverse with respect to climate change, each of which providing only a small component of the total information), and how to allow probability assignments to which subsets is going to be of paramount importance. This means that decision making to address climate change appears as a category of decision making which must envisage shifts to the traditional Bayesian scheme (Paté-Cornell, 1992, Caselton and Luo, 1994) when confronting to strong or even extreme uncertainties created by climate change¹.

The information and data issue brings us to better introduce the nature and representation of uncertainty, risk, and ignorance, first in economics, then with respect to climate change prospects.

¹ In decision making under “weak” uncertainty and risk, the analyst is provided with precise, either objective or subjective probabilities. When it is not possible to arrive at such a unique probability distribution for an event, one tries to construct it from more fundamental events. Such a procedure is known as the Bayes' rule. Suppose the hypothesis B is true and that an event A has occurred. Then, the probability of hypothesis B given that event A has taken place is given by $\wp(B|A) = \wp(AB)/\wp(A)$. $\wp(B|A)$ is known as the posterior probability and depends upon $\wp(A)$ which is known as the a priori probability. How do we obtain the prior probabilities? If there are past empirical evidences one can obtain the priors from them. But if there is no evidence available to us about, say, whether global warming or climate change of unacceptable level is going to occur or not, then, according to the “principle of sufficient reason”, one has to assign equal prior probabilities to all the mutually exclusive events (or to forget about the Bayes' rule if climate change simply does not allow to make prior probability assessments—Heap et al., 1992). In the first case, if new scientific information is forthcoming, one can use that information to update the prior probabilities or beliefs using the Bayes' rule to get the posteriors. In summary, the Bayesian theory yields instructions on how to use new information to update beliefs “rationally” in certain circumstances.

6.1.2 *Decision Problems under Uncertainty and Risk*

Climate change concerns give ground to a new situation with respect to uncertainty and risk. This means that responses will vary either. Here is a quick overview of the current responses to risk and uncertainty.

6.1.2.1 *Standard responses to uncertainty and risks*

Consider first *uncertainty*. The classical ingredients of a decision problem under uncertainty are a set of feasible acts (A), a set of consequences (C), and a set of states of nature (S). The decision-maker does not know for sure which consequence will result from a chosen act (probabilities for the events are not known in advance). The role of the states of nature is to indicate the matching of feasible acts to consequences, thus resolving the uncertainty which relates acts to consequences. This makes states of nature exogenous (uncertainty becomes in like manner exogenous, too) so that probabilities can be computed. As a result, the decision-makers basically have to assign utilities to the consequences (utility U assigned to each consequence c in C) and probabilities to the states (probability p assigned to each state s in S) (Schmeidler and Wakker, 1987).²

In choosing between acts, the decision-makers will elect that one with the highest “expected utility”—that is, the one with the highest sum of the products of probability and utility.

Second, consider *risk*. A decision making under risk introduces a special formulation of the decision problem to the extent that probabilities for the events are known in advance. In other words, the decision problem includes the probability distribution of an act over the consequences. Accordingly, decision-makers only have to determine utilities of consequences before choosing between acts. Typically, however, reducing risk entails a reduction of benefits (Starr, 1989).

6.1.2.2 *Uncertainty and Risk Decision Rules*

First, *uncertainty* approved collective/individual decision rules can be outlined as follows (MIT, 1986):

² A specific way allowing to cover the case for uncertainty—originally about the availability of resources and about consumption and production possibilities—is the idea of *contingent commodity* introduced by Arrow (1953) and developed by Debreu (1953). This device is added to the current specifications of the commodity such as its physical characteristics and location to make the availability of the commodity contingent on the occurrence of some (uncertain) environmental event such as weather conditions.

- 1 **Maximax** The decision maker should opt for that course of action which yields the
 2 highest pay-off (net benefits, or whatever) *regardless* of any view taken
 3 about which state of nature will occur. It's the optimistic rule.
- 4 **Maximin** ...We should first observe all the minimum pay-offs and then select the
 5 highest of these.
- 6 **Minimax regrets** ...We should select measures of “regret” (i.e., the difference between an
 7 actual pay-off and what the pay-off would have been if the correct strat-
 8 egy had been chosen). This is a cautious principle and ensures that, if the
 9 worst happens, we make “the best of a bad job”.
 10 ...We should seek to minimise the maximum regrets.
 11 ...We should seek to minimise maximum loss (Dowlatabadi and
 12 Morgan, 1992).
- 13 **Second, *risk* basic collective/individual decision rules can be outlined as follows (MIT, 1986):**
- 14 **Risk aversion:** Higher expected return as compensation for an increase in risk. A risk
 15 averter can be a diversifier and spread his *portfolio* over different
 16 assets—or a “plunger” and invest wholly in bonds and money.
- 17 **Diversifier:** Risk is likely to be the cause of *portfolio* diversification: if risks increase
 18 then the diversifiers will move back to holding wealth in the form of
 19 money.
- 20 **Risk lover :** A risk lover accepts a higher level of risk for a given expected return.
- 21 **Risk neutral :** A risk neutral individual would be indifferent whether or not he
 22 accepted “fair” insurance.

23 **6.1.3 *Uncertainty and Risk Revisited in the Context of Climate Change***

24 A useful four-part classification of choice variables is to consider decision making under certainty,
 25 risk, uncertainty, (Luce and Raiffa, 1957), and catastrophic risks. A classical description is given
 26 below while attention about climate change is gradually introduced.

6.1.3.1 Certainty

Certainty refers to situations in which chance is excluded because knowledge is sufficient. With sufficient knowledge, in other words, there would be no probability distributions, only certainty (Fisher, 1930, Arrow, 1951).³ Only simple cases and those treated in a perfect-information equivalent context fall into the certainty category.

6.1.3.2 Risk

Basically, risk refers to situations in which chance is included in the form of known probabilities. In other words, risk refers to situations where probabilities are knowable (Johansson, 1993), or where the size of the event has a probability distribution (MIT, 1989). Individual insurance decisions and for instance technical situations usually fall within the risk category.

In economic situations, risk is exogenous and individual. It is for instance expressed by a set of exogenous states of nature whose values are random. At the beginning of our understanding of economics, risk was thought as unimportant because of our capability at hedging and diversifying and since risks could be perfectly insured (Knight, 1921, *see* Bray, 1987). Knight's criterion was that "risk" was insurable while "uncertainty" was not inasmuch as the scientific method—namely the Bayesian scheme—could not be applied. This distinction has been since denied by many leading economists. The point is that from a Bayesian standpoint, a subjective probability can always be formulated "as a bet on a certain event" and a decision-maker's beliefs can always be represented by a unique probability measure (Vercelli, 1991). Therefore, to the extent that agents have fully reliable information about a unique probability distribution, the scientific method can still be applied and uncertainty is reduced to "risk"—reciprocally, risk applies to any kind of uncertainty.

The climate change context makes risk endogenous and collective (Chichilnisky and Heal, 1993). Risk cannot anymore apply to any kind of uncertainty with respect to the global environment. Indeed, climate-related risks cannot be expressed in a classical statistical sense (numerical probabilities) because of a lack of experiments, poor data and/or diverse data sources. For the insurance industry itself, circumstances have changed "in ways that mean traditional practice and the old statistical methodologies are no longer adequate"—"past experience is no longer a safe guide to the far future"

³ To formalise the conditions of certainty (and later on, of uncertainty), it is convenient to refer to Arrow's concept of *state of the world*, a description of the world so complete that, if true and known, the consequences of every action would be known. The meaning of certainty is that the agent *knows* the state of the world.

(Ayres and Weaver, 1994). Climate change implies a certain degree of irreducible unpredictability beyond the economic category of risk like uncertainty. This unpredictability arises in two ways. On the one hand, it appears with regard to the future structure and outcomes of any nature-economy joint system. On the other hand, it exists with regard to the characteristics of the evolution (rate, abruptness, etc.) of the processes involved.

In total, the “unpredictability” of climate changes gives rise to a kind of uncertainty which might not be straightforwardly reduced to Bayesian risk (see Tables 6.3 and 6.4).

6.1.3.3 *Uncertainty*

Uncertainty proper, contrary to risk, has always been thought of having an important effect on the workings of the economy. It refers to situations in which chance is included but knowledge is insufficient: Probabilities cannot even be defined (Johansson, 1993). In other words, the likelihood of an event occurring is *not known at all* (MIT, 1989) and the events upon which decision outcomes depend are not controlled by the decision agent—consequently, they are only known after the decision is made (Fishburn, 1987)—though any actual decision creates a new starting point. In decision makings under uncertainty, therefore, no probability distribution can be attached to the outcomes—e.g., conceivable outcomes will be known, but their probability of occurrence will not. According to the concept of state of the world, the meaning of uncertainty is that the agent does *not* know the state of the world (Arrow, 1971, 1984).

Yet, in the conjunction of utility theory and decision theory, probabilities of the events are considered as assessable although with reference to personal judgement. In this case, indeed, the criteria for choice are to be based on numerical representations of the decision agent's preferences and values. The condition for making uncertainty computable is that agents at least believe that they know, even approximately, the relative frequencies of the states of nature. As a consequence, the Bayesian scheme applies to uncertainty situations as it does with respect to risk situations. This risk-like kind of uncertainty is generally referred to as “weak” uncertainty while “strong” uncertainty indicate uncertainty proper—in other words situations for which probabilities cannot be defined.

6.1.3.4 *Catastrophic Risks*

The risks may be substantial. Climate changes have the potential to alter the natural setting of the earth through droughts, productivity of forests, coastal erosion, to name a few outcomes. Climate

changes can induce non-linear, abrupt, and high impact consequences: Change in ocean circulation patterns, liberation of methane in currently frozen sediments, melting of Antarctic ice sheet. Catastrophic risks break a new ground in the analysis of nature-economy systems because (a) the scope is global on the nature side, and (b) the change in circumstances is man-induced.

These risks are however still depicted as surprises and/or as natural hazards (extreme weather events). They are characterised as low(er) probability – high impact scenarios (Fankhauser, 1994). Nevertheless, extreme-event probabilities associated to coastal inundations have been underestimated. In this case, the reason is that data from the recent past showed insufficient variability to provide guidance on possible rates and extents of sea-level change (Tooley, 1994).

Like severe industrial hazards, environmental hazards are not straightforwardly defined. Querner (1993) defines a severe hazard as a public, physical risk: (a) with a very low probability of the adverse event (unlikeliness); and (b) a possibly very large death toll (catastrophiness). Compared to “normal” physical risks, catastrophic hazards are characterised by (a) an extremely small expected number of accidents (EA), (b) a very high expected number of fatalities per accident (EFPA), (c) still constituting only a very small average individual death probability μ , which equals $EA \times EFPA$ over the number of people exposed to the hazard (Querner, 1993).

Getting back to global environmental hazards, they also are considered as unforeseen environmental and economic losses (the ones for which the insurance and reinsurance sectors have been forced to take the “hit” despite their short-term vision on the future and their fixed contracts policies). *One cannot rely upon commercial assurance neither to compute nor to cover catastrophic risks associated to climate change.* These losses are not so readily quantifiable. In order to assess such catastrophic risks, society basically needs better information on the resilience of the environment, the rate of environmental change, the probabilities of extreme events, and vulnerability (INSEAD/SANDOZ, 1994).

6.1.3.5 How to address uncertainty and risk associated to climate change?

It is usual to alternatively speak of risk, uncertainty and even ignorance (incomplete information).

Climate change, however, suggests that we clarify the distinction between risk, uncertainty, and ignorance, and that we consider its implications in relation to the decision making framework.⁴

⁴ Other important factors such as time, information, discounting, irreversibility, fairness across generations, and scientific results—which all affect decision making under risk and uncertainty—will be introduced and developed in section 2.

Table 6.3—Climate change related uncertainties

The rise in the accumulation of greenhouse gases is agreed upon though, basically, uncertainties are attached to energy-related carbon emissions, to regional carbon emissions as well as to the range of cumulative energy-related global carbon emissions and associated variables such as population, and economic growth (see Chapter ...). What is then uncertain are the pace and extent of climatic impacts such as rise in temperature, rise in sea level or abrupt changes as well as occurrence of extreme events and thereby changes in ecological balances of biosphere. It is expected that efforts to contain these impacts and offsetting them would have significant economic costs (with costs in front and benefits being heavily discounted).

Uncertainties that are associated with potential climate changes can be categorised into the following groups:

- (a) Scientific uncertainties associated to the *effects of emissions of greenhouse gases on climate change*:
 - mean temperature rise
 - sea level rise
 - reduction of moisture, precipitation changes
 - pace/abruptness of changes.
- (b) Scientific uncertainties attached to *how much impacts different levels of climatic variables might have*:
 - biomass productivity, e.g., that of agriculture and forests
 - species loss (terrestrial and marine)
 - other discomfort and damage costs (replacement costs, e.g., cost of increased air-conditioning, etc.)
- (c) Economic uncertainties about the extent and nature of the *economic impacts* caused by these physical impacts :
 - effects of global warming on per capita, national and regional incomes
 - efficiency of actions designed to mitigate/adapt/control/understand human environmental loading, the climate system, and its interactions with the biosphere (Dowlatabadi and Morgan, 1993)—for instance as unit of income per unit of impact
 - possible benefits of abatement actions, if taken to avoid global warming (costs, because they are in front, are known with more certainty than future benefits); costs per ton of Carbon will vary, beyond the carbon savings target, with the extent by which damage due to climate change, on the one hand, and benefits, including side benefits, on the other hand, are internalised.

Figure 6.1 shows a schematic linkage between scientific uncertainties and impacts uncertainties.

To say the least, if the occurrences facing an agent can be expressed in terms of specific numerical probabilities, or if the agent knows or believes that he or she knows—at least approximately—the relative frequency of the states of nature, then the situation can be said to be a risk-like situation. In other words, if the parties believe that the relative frequencies of the events at issue are at least approximately known, risks can potentially be allocated (Chichilnisky and Heal, 1993). It turns out that uncertainty, as defined with respect to such situations, is reducible to risk. As a consequence, this “weak” form of uncertainty can be dealt with according to the scientific method and the expected utility maximisation scheme.

Conversely, if one cannot assign actual probabilities to the relative frequency of the states of nature, or does not know it at all, or does not at least believe in any probability distribution, the situation can be said to involve uncertainty proper. In these circumstances, society is facing true uncertainty.

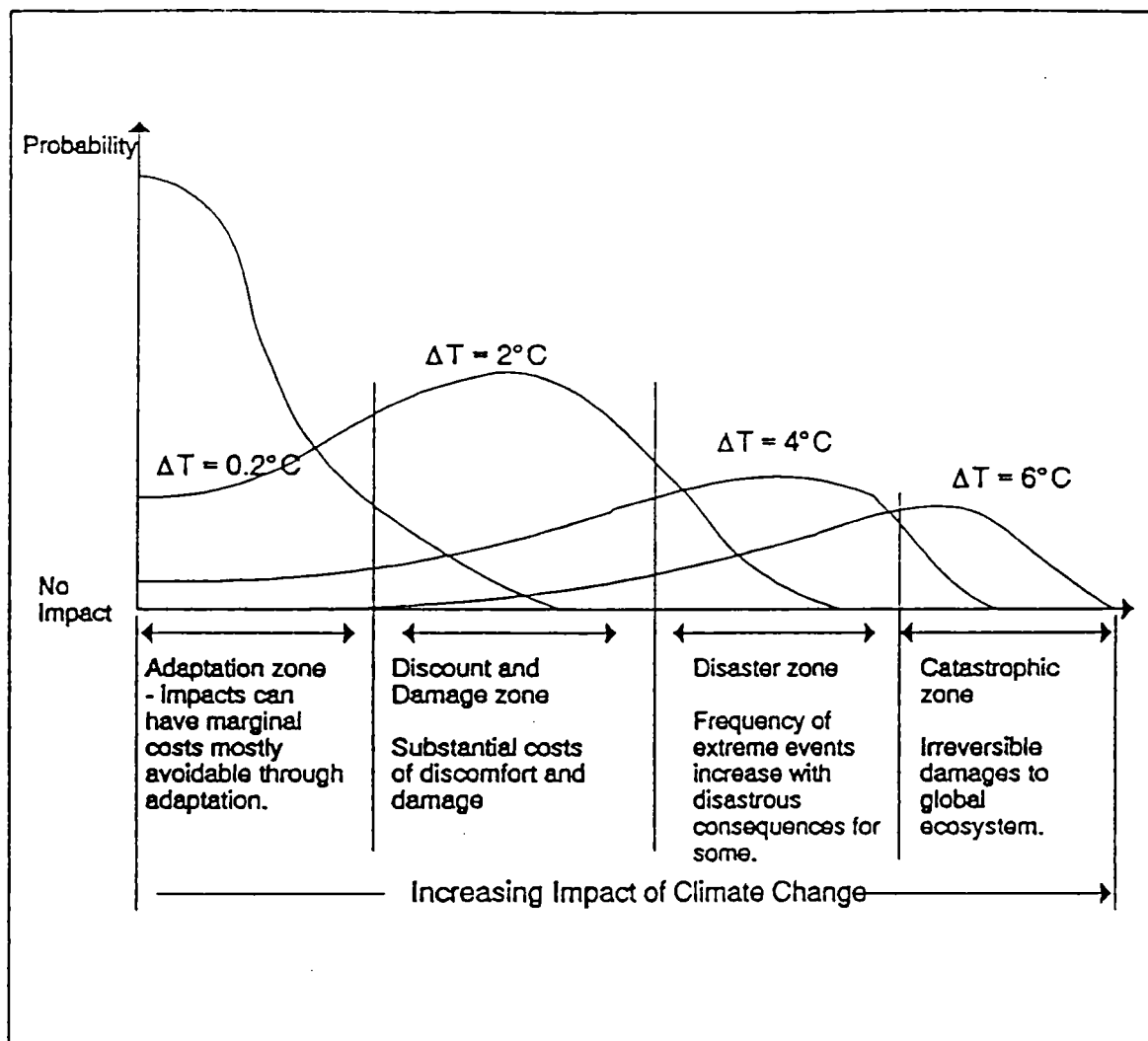


Figure 6.1: Schematic linkage between scientific uncertainties and impacts uncertainties

Area under each probability distribution curve is 1 (probabilities are thus additive to simplify matters, although "strong" uncertainties should require non-additive probabilities—Beltratti, 1994).

At $\Delta T = 0.2^\circ\text{C}$, the probability that there is no impact is much larger than at $\Delta T = 6^\circ\text{C}$. Reverse is the case for the catastrophic zone. Similar relationships may be plotted for different levels of sea level rise. After Parikh et al., 1994.

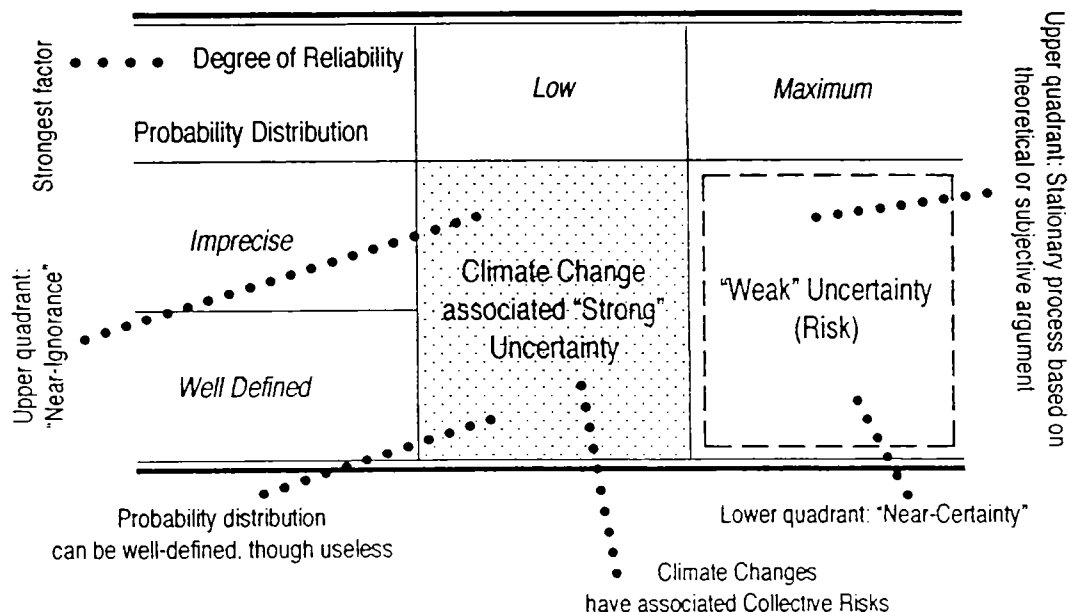
Accordingly, "strong" uncertainty would be characterised by the absence of reliability with respect to some existing probability distribution, if any, while near-ignorance would be characterised by lack of information and absence of believability as well (both suppose a weight of argument). The existence of "strong" uncertainties implies to consider at least two different issues at two different levels; that is, (a) the existence and reliability of statistics and/or probability distributions (Vercelli, 1991), and (b) present versus distant future preferences (Chichilnisky, 1993).

The concern about the existence and reliability of statistics and/or probability distributions designates a reconciliation framework for risk and uncertainty (see Table 6.4). According to various contributions, let's define the case for "weak" uncertainty (risk) where only one probability distribution is possible (even on a theoretical basis) and its degree of reliability is the maximum, and the case for "strong" uncertainty (near-ignorance) where, even with regard to a well-defined probability distribution, the degree of reliability is low because of the existence of an unavoidable gap between competence (of the agent or of society) and difficulty (of the problem)—to illustrate, learning should be assumed to be successful to generate a convergence towards a fully reliable probability distribution.⁵ Under "strong" uncertainties, however, we don't know the full range of possible outcomes: To know it, we would have to know the future growth of knowledge, and how this will affect the world (Heap et al., 1992)!

The present versus distant future issue addresses social choice via maximum utility and fairness across generations. Chichilnisky's (1993) axiomatic construction requires an equal (or non-dictatorship) treatment of the present and of the future. This eliminates pure (discounted) maximisation of utility. In future, *sustainable preferences* will constitute the welfare—or, social choice—criterion.

Table 6.4—A Climate Change Related Risk versus Uncertainty Framework

Source: Adapted from Vercelli (1991), Faucheux and Froger (1994), Froger and Zyla (1994), and Pillet (1994)



⁵ By way of illustration, 50 years of data collection about floods in Southern France can be treated as a probability distribution though it is useless with respect to the global time scale associated to changes in climate (Tooley, 1994).

According to a model by Heal (1993) and subsequent developments by Chichilnisky and Heal (1993), Beltratti (1994), and Pillet (1994), the reaction to “strong” uncertainty translates into a consumption increase. Interestingly, this effect—or, “strong” uncertainty aversion—indicates that in the short run – long run trade-off, consumption today dominates the equation, which is similar to the discounted utilitarian perspective, but sets in contrast to the precautionary principle that is supposed to satisfy the long-run future.

Table 6.5—Risks Associated to Climate Change

Climate change associated risks are:

- *endogenous*—they are affected by our actions
- *correlative*—they are not statistically independent risks.

They are defined as affecting large numbers of people in the same way. Think for instance about a 10 percent chance that 90 percent of the population will be harmed by global warming, a 25 percent chance that 50 percent of the population will be harmed, etc. After Chichilnisky (1994).

Climate change risk positions might be traded on the international scene (cf. 6.3.3).

Regarding decision criteria and standard responses to risk and uncertainty, the shift to “strong” uncertainty from standard risk-like situations has different implications. In particular, this must lead to revise the atemporal repertoire of the ready-to-use decision rules if one wants to address decision making with respect to climate change. This also has implications on how to make decisions in the sense that this is also a shift to options making (equal sensitivity to the present and to the future, insufficient knowledge and insufficient competence and statistics) from standard decision making (sensitivity to the present, sufficient statistics, knowledge, and competence).

Last, other factors that are specifically connected to climate change will influence decision making. Basically, one must consider that beyond the global character of climate change prospects, different countries are facing different risks and their perceptions also differ. In addition, if one cannot arrive at a global welfare function for a country by aggregating individual utility functions, one cannot infer some global welfare function from individual countries' ones, either. Section 6.2 is a step towards alternative factors that affect decision making for countries that have different capacities, welfare, and attitudes towards climate change “strong” uncertainties and collective risks.

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6.2 Factors that Affect Decision Making

As seen in Section 6.1, responses to uncertainty and risks associated to climate change might shift from standard decision rules based on sufficient statistics, knowledge, competence, and sensitivity to the present to rules that would accommodate to insufficient knowledge, competence, statistics, and symmetric sensitivity to the present and to the future. Section 6.2 is devoted at actualising this by looking through main factors that will influence climate change related decision making. To simplify matters, these factors have been arranged into three categories: first, factors that are linked to temporal economic analysis such as information, irreversibilities, and discounting; second, socio-economic considerations of equity, poverty, and attitudes; and third, scientific insights that are emerging with respect to the behaviour of the climate system.

6.2.1 Time

We have presented decision making as a one-shot process. In reality, however, one needs to make a series of decisions. For instance, the International Negotiating Committee might be willing to wait for more information before deciding which levels of global carbon emissions are desirable. Before the information succeeds, one might have to take decisions regarding other issues (Parikh et al., 1994).

In particular, risks associated with such cases is known as temporal risks. In such *temporal situations*, as Machina (1984) pointed out, risk aversion is higher compared to the case of atemporal choices, and events with low probability (unlikeliness) and a possibly very large death toll such as catastrophes become more important compared to "normal" physical risks (see 6.1.3.4, supra).

Risky elements also lead to the role of interest for discounting. Basically, climate change is long-term oriented and is very large on the scale of the economy. It cannot be dealt with by private actions on this scale. Therefore, governmental actions are required, which are risky ones, and which consequently call for considerations about discounting, and other issues such as irreversibilities, insurance, and so on.

6.2.1.1 Information, value of information

Will information, will more knowledge resolve uncertainty? Conventionally, improving information and knowledge should resolve uncertainties. As a practical consequence, learning strategies are included in decision making in the form of sequential decision processes (Hammit et al., 1992).

1 For instance, learn-then-act strategies can be balanced against act-then-learn options (Manne and
2 Richels, 1992, Peck and Teisberg, 1993). In addition, there is a fairly agreement on improving our
3 understanding of the climate change problem (Peck and Teisberg, 1993). This led to the analysis of
4 the *value of information* about global warming.

5 According to Peck and Teisberg (1993), a resolution of uncertainty has high value relative to
6 current research budgets.¹ Moreover, Peck and Teisberg (1993) points out two interesting results. On
7 the one hand, they found that there was *not a high premium on immediate resolution of uncertainty* in
8 as far as this would occur within, say, twenty years. On the other hand, they found that “if the real
9 world political process would result in a suboptimal control policy being chosen under uncertainty,
10 and this choice could be prevented by early resolution of uncertainty, the *benefit of early resolution*
11 *may be as much as three orders of magnitude greater*”. This constitutes a fair criterion if one wants to
12 look into alternatives to current policy responses that could override both suboptimal policies and the
13 difficulty at solving *now* “strong” uncertainties.

14 The decisions we make as well as the results of the simplest models we run to simulate the
15 outcomes of decision-makings are contingent upon the level of information we possess—e.g., about
16 climate change prospects and impacts—or that is assumed to be produced with time. As a matter of
17 fact, progress in knowledge will have much influence on the decision to reach as well as on the
18 decision process itself. This will for instance update the distribution of probabilities for the
19 subsequent years (Peck, 1994). As one another example, the possibility of future learning will
20 influence current period decisions: facing a project which is reversible, learning leads to a lower value
21 of the current period decision. Learning more about the net benefits of the investment at a future date
22 will still allow subsequent investment decisions to be made (Ulph and Ulph, 1994).

23 A widespread assumption is that scientific knowledge will linearly increase with time, and give a
24 perfect information after n years. This analysis proceeds as if we had—in principle and at any step—
25 the opportunity to learn the state of the world before taking action (Manne and Richels, 1993). No
26 information is forthcoming once the decision is taken; e.g., by the next period. This analysis is
27 typically shared by deterministic models, which assume that all uncertainties are resolved *prior to*
28 decision making.

¹ And “resolving uncertainty about the cost of warming is nearly as important as resolving uncertainty about the extent of warming”.

1 The most plausible assumption, however, is that uncertainties *will not be completely resolved with*
2 *time*. This leads to integrate information in decision making under uncertainty and risk by
3 incorporating the opportunity for learning into the decision making framework; that is, by making the
4 decision process an ongoing, for instance an “act—then learn” process (Manne and Richels, 1992,
5 1993). In other words, incorporating information means making uncertainties endogenous and, there-
6 fore, entering a sequential-decision process. This also means that learning will be endogenously used
7 to revise the distribution of probabilities for the years to come. Such a strategy come into play in as
8 far as we know that any action set up now will need to be revised later (Hammit *et al.*, 1992). On the
9 one hand, as scientific understanding of climate change improves and, on the other hand, as economic
10 actions evolve and uncertainties are nearly resolved.

11 Finally, one must recognise that not every progress in knowledge is synonymous of reducing
12 uncertainties. For example, the ozone layer issue has shown the contrary (Mégie, 1992). In many
13 cases, progress in knowledge can even stress uncertainties because of the circular causality and non-
14 linear cause-effect relationships in science (Gassmann, 1994).

15 Incorporating information into decision making and thus entering a sequential decision making
16 process means that forthcoming information carries a value. In other words, waiting for information
17 bears a value which can be computed as the option value of preserving an environmental asset. This
18 “option value” can be defined as the gain from retaining the option to preserve or develop an area in
19 the future (Krutilla, 1985); in other words, the gain from being able to learn about future benefits of
20 not developing that area initially. A quasi-option value is defined as the increase in expected net
21 benefits of not developing the area initially when the decision maker can make the decision after
22 uncertainty is resolved (Johansson, 1993).

23 Basically, this value is born from the existence of uncertainties around the future benefits
24 associated to the action taken now and the uncertainty about future generations and preferences. This
25 refers to the cases for leaving more resource to the next generation, for conserving an ecological
26 asset, when consumption is an irreversible depletion of a stock, and when emissions affect the global
27 climate (for preserving the atmospheric environment). Indeed, the benefits from the preservation of
28 the (natural) asset will accrue in the future and—similarly for future preferences—are yet unknown.
29 As a rule, waiting for information will save the option of reconsidering the decision about to preserve

1 the resource when improved information becomes available. In other words, economists allow for a
2 future reduction of uncertainty by incorporating option value.

3 Preventing climate change—what acting strongly now would depict—should thus be credited with
4 an option value, the value of waiting for scientific knowledge about the greenhouse effect. In a
5 development versus conservation context, if the decision maker does not anticipate for better
6 information (does not allow for a future reduction of uncertainty), first-period development could be
7 too great (Krutilla and Fisher, 1975, 1985). There is some controversy about expanding this result to
8 the class of global warming problems (Ulph and Ulph, 1994).

9 Yet, option value is not identical to the value of information in a development decision problem.
10 On the one hand, option value is conditional on a particular choice of first-period development
11 whereas the value of information, which basically is the expected value of perfect information, is
12 unconditional. Option value is thus connected to contingent decisions. On the other hand, the former
13 can be equal to or greater than the latter.

14 Last, a good number of authors have established that option value was identical to a risk premium,
15 and that it could be negative because preservation, and not only development, can bring risks.

16 In sum, incorporating information into decision making processes makes subsequent decisions
17 *contingent* upon future resolution of uncertainties and upon attitudes toward risk.

18 Yet, it might appear in the interval that increasing scientific insights would also result in a
19 decreasing capability in establishing climate change forecasts (see 6.2.3, *infra*). In other words, more
20 knowledge might mean more uncertainty instead of inferring more certainty.

21 What in fact happens is that, on the one hand, by additional knowledge, we realise that our view of
22 climate dynamics was too simple being too much influenced by classical linear systems. So, the new
23 results widen the spectrum of possible reactions of the global climate system to the anthropogenic
24 CO₂-input and clearly, this widening results in an increased uncertainty. On the other hand, however,
25 by anticipating more possible reactions, the surprise potential is reduced and so is the probability of
26 unfavourable response strategies. This new view about the relationships between knowledge and
27 uncertainty rests on the assumption of a shift to abrupt—either regional or global—climate changes
28 (see 6.2.3, *infra*). Therefore, response strategies and decision processes that want to address *abrupt*
29 climate changes should be robust enough to be supportable even once some unforeseen abrupt climate
30 change happened.

“Waiting for information” has also been explored on a more substantial basis in the context of the Arrow-Fisher-Henry irreversibility effect (1974)—see *infra*.

6.2.1.2 Irreversibilities

Irreversibility has come to be known as an important choice variable in decisions that have uncertain, though not reversible consequences.

This decision factor evolved from economic-like situations dealing with special environmental features as for instance unique natural environments and wildlife resources. These situations led to identify a new approach for making allocation decisions because of the existence of resources with no, no adequate, or at least a few substitutes (uniqueness does not need to be absolute for the argument to hold). The features that Krutilla (1967) identified are multiple. One of them is this: in this category, the (natural resource) allocation decisions are irreversible.

This conclusion gave rise to a conservation versus development debate. One noticeable consequence has been that efficient control policies might mean some restriction of the activity.

According to Arrow and Fisher (1974) irreversibility can be alternatively defined as follows: “A technically irreversible development could be characterised as one that would be infinitely costly to reverse”.

With respect to climate change/technology linkages, the state of the world beyond ten or twenty years from now cannot be carefully thought about as independent from today's decisions. The consequence of this non-independence is the formation of irreversibilities (basically, the fact that there is no possibility of “negative emissions”, that there is no process for removing CO₂ emissions from the atmosphere once emitted, makes the emissions of CO₂ irreversible).

In other words, this non-independence is responsible for the existence of irreversible or quasi-irreversible trends in technology because of lock-in effects for example in consumption and land-use patterns (Hourcade and Chapuis, 1994).

On the decision making side, irreversibility predominantly leads to risk averse type decisions (e.g., portfolio diversification, no-regret policy, minimum surprise). Note that there is some controversy about expanding *development versus conservation* results to global warming problems. Conventionally, the belief is that if the decision involves irreversibility, then current period decisions should involve less irreversible commitment (one should undertake less irreversible investment) if there is

the possibility of future learning than if there is no such possibility. Although irreversibility and learning seem to have opposite effects on the current decision period, “whether there is learning or no learning, there will be less investment when investment is effectively irreversible, than when investment is reversible” (Ulph and Ulph, 1994). Does this means that irreversibility requires lower current emissions of greenhouse gases?

6.2.1.3 Discounting

In conjunction with uncertainty, risk, and the need for capturing forthcoming information, time also introduces the discounting of future benefits and costs.

Abatement as well as adaptation strategies are costly. Uncertain benefits are attached to such actions. Long-term costs and benefits are uncorrelated to national incomes.

Climate change, as already said, is big at the scale of the economy. Therefore, actions are requested from governments (no private action can be a key action on this scale). These actions are risky. The risk might be that your don't abate enough. Or too much. Discounting costs and benefits becomes of paramount importance in the valuation of outcomes.

At which rate do you have to do that? The overnight rate of interest, as business does? Bond rates? The pure rate of interest? A discount rate below the pure rate of interest? Or do we have to favour a zero discount rate?

Let R be the current rate of interest. Basically, R is a mixture of pure rate of interest (r) plus some allowance for risk. In other words, $R = r + \text{some risk premium}$. In this respect, we actually buy some insurance because of aversion to risk (because we expect to loose money) (Arrow, 1994). Now, this aversion to risk also means a preference for the present. In other words, the preference for the present translates into heavily discounting the future.

Which discount rate to choose is an important question since the result of any cost or benefit calculation over time is highly sensitive with respect to the discount rate's value. Schmalensee (1993) points out that in an example that in order to pay a US\$1 billion damage in the year 2200, one has to spend in 1992 US\$ 126 million on basis of a 1% discount rate of US\$ 32,000 on basis of a 5% discount rate. Cline and Nordhaus present similar examples (Cline, 1992, Nordhaus, 1991). To illustrate, the present value of \$ 1 obtainable in 200 years from now amounts to \$ 1 if the discount rate is zero, to \$ 0.14 if the discount rate is 1%, to \$ 0.000058 for a 5% discount rate or to \$ 0.00000000527 for a

1 10% discount rate. These examples indicate that a moderate change in discount rate results in a
2 significant change of the evaluation of spending amounts over time (see Schubert, 1994).

3 The argument that the discount rate should be greater than zero is usually based on the assumption
4 that it represents individual's time preferences which should not be denied. The value of this
5 argument depends on the interpretation of the meaning of "discount rate"; i.e., on the answer to the
6 question "what is to be discounted?" (Broome, 1992). In general, two different interpretations of
7 "discount rate" are of special importance; that is, the social time preference and the opportunity cost
8 of capital. Whereas the first one represents the marginal utility of today's consumption as compared to
9 future consumption, the second one indicates the profitability of private investment. Usually, this
10 second rate is significantly higher than the first one. The reason is that for private investors the rate of
11 return on the best alternative project that is displaced by the investment under consideration depends
12 on various capital market imperfections whereas the time preference reflects the interest rates
13 available to consumers. Since consumers are net savers, the interest rate they have to pay (R) is less
14 exposed to risks (the risk premium is lower) and therefore lower than the real net rate of return of
15 producers.

16 For calculating the social time preference, typically two aspects are taken into consideration
17 (Pearce et al., 1990). The first one is that individuals are impatient and prefer the present to the future.
18 Their exposure to a limited life span might underline such preferences. If society is taken as the sum
19 of its individuals, it also prefers the present to the future. Such temporal preference leads to a positive
20 discount rate. The fact is, however, that climate change is away from the scale of private, individual
21 actions.

22 Indeed, there exists a variety of arguments against this aspect of social time preference. Nearly all
23 of them go back to Jevons' argument that impatience is irrational and therefore in contradiction to the
24 behavioural assumptions used for explaining choice behaviour (Jevons, 1871, Böhm-Bawerk, 1884,
25 Ramsey, 1928, Pigou, 1932). Nevertheless, impatience is observable so that this aspect should not be
26 fully denied. One another implicit argument against impatience has been forged by Chichilnisky
27 (1993). One can summarise this argument through the twin axiom of non-dictatorship of the present
28 and of non-dictatorship of the future. While non-dictatorship of the future eliminates deep ecological
29 "long-term average" solution, the non-dictatorship of the present eliminates discounting.

As suggested by Schubert (1994), one also has to take into consideration empirical studies on the existence of discounting. According to these studies one can show that, in general, consequences expected to occur later in time are regarded as being less important (Björkman, 1984, Jungermann and Fleischer, 1988, Svenson, 1991). Two explanatory cognitive patterns have been identified (Van den Berg et al., 1993). One is that more remote consequences will be judged as being less serious (i.e., value discounting). The other is that such consequences, if a certain controllability is perceived, will be thought of as less probable to occur (i.e., probability discounting).

As a consequence, whatever the explanation may be, empirical and especially experimental studies seems to support clearly the discount rate greater than zero position. In conjunction with economic analysis, it seems that, in principle, a low rate of discount is advisable (Arrow, 1994). As determined by Cline, a discount rate of about 2% should be used for evaluating projects that are directly thought for fighting global warming. Why (World Bank's statements are in favour of an effective discount rate of about 8%)? Cline correctly assumes that 80% of project's resources come from consumption and 20% from investment expenditures. Indeed, recall that, in principle, R is lower for consumers than for producers. The fact is that governments must take actions, but that these actions are going to be fuelled much more through withdrawals from consumption than from investment expenditures.

Conversely, the main reason for a relatively high discount rate would be that any project directed to fight global warming should yield at least the same project profitability as any other (World Bank) project (i.e. 8%). The point is that this would be valid only to the extent that, in order to allow an equal treatment to different projects, negative externalities (which, indeed, are connected to climate change) be included in any project's calculation (Pillet, 1992, Broome, 1992, Schubert, 1994).

6.2.1.4 *Costs, benefits*

Costs and benefits refer to the valuation of outcomes (alternatively of decision or response options). In the climate change context, there exists not only economic outcomes, but also ecosystem outcomes. The former are for instance world income losses, costs of delay, cumulative social costs. The latter are made of losses to the unmanaged ecosystems, including species and habitat loss. Potential benefits of slowing down climate change have to be assessed, too.

How one values these outcomes, including benefits—particularly economic ones as opposed to ecosystem ones—, how this valuation depends on the uncertainty, and how averse one is to risk, will

influence the decision to reach as well as the process which will optimise expected value (Peck, 1994).

[to be completed by J. Parikh]

6.2.2 *Attitudes*

While the picture of division of responsibilities for global warming is known (for example, OECD was responsible for nearly 50% of gross global CO₂ impact in 1990 while Africa for nearly 2% only—Meyer and Sharan, 1994), the picture of vulnerabilities is known with much less certainty. In addition to economic parameters, the decision making framework must thus address questions like equity, poverty and ethics.

6.2.2.1 *Equity, poverty and global warming*

Generally speaking, the poor are more vulnerable to any calamity compared to the well off. For instance, while the Netherlands can build more dykes, nearly half of Bangladesh could be expected to submerge due to possible increased floods and sea level rise, increasing poverty and homelessness. Some island states face the fear possibility of disappearing from the map of the earth.

Large scale out-migration from coastal zones is expected due to sea level rise. More than seven million persons may be displaced from coastal zones in India. Large cities like Bombay, Calcutta and Madras are on the coast (Parikh et al., 1994).

Intrusion of sea water in the ground water and changes in temperature can reduce agricultural incomes everywhere, if any. In Bangladesh, the share of GDP due to agriculture is 38% compared to only 3% of GDP in the USA (World Development Report, 1992). Share of population depending on agriculture is also more than 60% of the population in Bangladesh.

One can therefore envisage that the impact of climate change on the poor of the South could be relatively more destructive than in the North. This raises the question of compensations, for instance in the form of insurance contracts, to be provided by the North. Immigrations rights might also be provided by the developed countries.

“While the rich can argue about whether to enjoy more now or pay more in the future, and what discount rates to use, this is not the issue for the poor, many of whom on the margin of subsistence have no option but to reduce their current consumption” (Parikh et al., 1994).

1 In sum, on the one hand, the poor might bear a disproportionate burden of changes in climate pri-
2 marily caused by the lifestyles and consumption patterns of the rich (Parikh et al., 1994). On the other
3 hand, conversely, one cannot isolate poverty from political, social, regional, cultural, demographic,
4 and environmental factors. Some regions of the world already are overpopulated in terms of the
5 maximum population that can be supported indefinitely in a given environment. In this respect, cli-
6 mate change would increase the pressure on the limits of the conditions on which life can be sup-
7 ported in some fragile life-support systems (Pillet, 1991). Losses in terms of natural capital in these
8 regions would inevitably make the poor poorer. What is to be first addressed under these circum-
9 stances is the threat to the natural carrying capacity of such regions, which of course is not
10 independent from local and regional economic and life-style options to make for the future.

11 6.2.2.2 *The ethical problem: anthropocentric vs. ecocentric evaluation*

12 As vulnerable as poor people are, the natural capital may be affected by global warming even before
13 mankind notices the change. The earlier IPCC impact assessment indicates substantial pressures on
14 biosphere and biodiversity due to climate change. For example, bleaching of coral reefs is expected
15 due to upward movement of temperature zones. Within the rest of the ecosystem, loss of species is
16 also indicated (Parikh et al., 1994).

17 Loss of species or damage to biodiversity has been traditionally ignored in the decision making
18 framework. Only recently researchers have started developing tools for valuing the environment .
19 Efforts to value species are mostly anthropocentric evaluations (economic valuation methods “value”
20 the preferences of individuals or society for the environment, not the environment per se—Pethig,
21 1994). In other words, values refer to the pleasure and service of *mankind*, be it for recreation,
22 medicine, education, research, chemicals, biochemical and other ingredients or to derive raw
23 materials for a variety of purposes (Parikh et al., 1994).

24 An ecocentric view, on the other hand, views mankind as *one* of the species on the planet earth
25 expected not just to live in harmony and balance with other species but also to share the biosphere
26 including oceans, atmosphere, rivers, and so on which provide sustenance to other with other animals
27 and plants. It does not make a judgement on other species but judges itself from the view point of
28 others. To put it sharply, mankind's abrogation of decision making powers regarding nature is
29 questioned; the ecocentric approach proposes to curtail such decision making power. The link

1 between the existence of other species and that of human beings should be kept in mind while
2 making any decisions regarding the activities of mankind which will adversely affect the environment
3 and other species (Parikh et al., 1994).

4 This is an issue of values. We raise it here to emphasise that whatever decision making framework
5 is adopted, the value judgement implicit in it should be made explicit.

6 6.2.2.3 *Distributional aspects :interregional and intergenerational equity*

7 [To be completed according to Parikh et al. and Shlyakhter et al.]

8 6.2.3 *Scientific Results (Gassmann, 1994)*

9 The anthropogenic nature of CO₂-increase found wide acceptance in the scientific world and cause
10 public concern very recently. However, the acceptance of an anthropogenic CO₂-increase is only half
11 the way to the acceptance of anthropogenic climate change.

12 6.2.3.1 *Climate change: Waiting for observation or learning from the past?*

13 Even with acceptance of the anthropogenic nature of atmospheric CO₂-increase, many scientists,
14 politicians and the public have a deep natural belief in the stability and robustness of the climate
15 system by trusting yet unknown negative feedback-loops guaranteeing homeostasis. Indeed, our
16 Holocene climate showed a seemingly convincing stability and steadiness over the last 10'000 years
17 with fluctuations of only plus minus half a degree (global average temperature) as derived from the
18 most recent Greenland ice core. Slow variations known as "Little Ice Age" or medieval optimum are
19 modulated with irregular short term variations with periods of the order of 30-100 years. The well-
20 known interannual variability due to the detailed evolution of high-and low-pressure cells that are
21 affected also by dynamical processes with inherent irregularity as "El Niño" are not taken into
22 account in the framework of the climate discussion. This by defining climate as the average state of
23 the atmosphere over an integration period of 30 years. Other causes of short term fluctuations are the
24 regular 11-year sunspot cycle as well as irregular volcanic eruptions. These short term variations can
25 hide continuous anthropogenic climate changes over several decades. If the prognosticated
26 anthropogenic trend of +0.3 K per decade would be reality, the global temperature signal will be
27 clearly out of the noise level by the years 2010-2020. It is a cheap and therefore widespread excuse
28 against taking measures to reduce greenhouse gas emissions, delegating any decision to the next
29 generation that will better see what happens.

1 It does not seem promising today, that theoretical model calculations alone will have power
2 enough to convince public and politicians in the next future of the alarming situation of planet earth.
3 Fortunately, paleoclimatology provides information about past climatic variations that are very close
4 to direct observations. Most astonishing, the picture drawn by the newest ice core results emphasises
5 variability and instability in a very unexpected way. Not only shows the last ice age a big number of
6 sharp transitions between a glacial and an interstadial climatic regime but also reveals the last
7 interglacial "Eem" as being composed of a series of climatic transitions. The largest uninterrupted
8 interval of Eem climate optimum (roughly 2K warmer than our Holocene level) encompasses only ca.
9 2500 years and at least 20 very important abrupt climate transitions to the Holocene, the interstadial
10 and even to the glacial level and back to the Eem level can be observed. The most catastrophical
11 fluctuation yet analysed happened towards the end of the Eem-interglacial (115'000 years ago), where
12 the Eem climate changed into a glacial climate within about 15 years, to make the same abrupt
13 change back to the original warm climate only 70 years later!

14 All the important processes influencing the global climate are identified and can be understood at
15 least in principle. Very detailed knowledge is available concerning long- and short-wave radiation
16 transport through the atmosphere. Especially, gases influencing the greenhouse effect are analysed in
17 detail (absorption bands, infrared emissions, diffusion) and so, its anthropogenic modification can be
18 rather exactly calculated. However, the basic assumptions made in such calculations are that the
19 structure of the climatic system remains unchanged. Especially, atmospheric and oceanic circulation
20 patterns and cloud formation are assumed to be qualitatively unchanged, at most being quantitatively
21 slightly affected and so contributing to a positive or negative feedback, amplifying or damping
22 climate effects respectively.

23 This means, that today's models simulate climate changes as marginal variations around a stable
24 basic climate mode. That the dynamics of this basic mode could dramatically change, being replaced
25 by a different one, is out of the scope of such models. Consequently, they are not able to simulate ice
26 ages as a whole nor the numerous and important climatic fluctuations within the last ice age or the
27 Eem. Easy to understand, that the prognosticated anthropogenic warming is gradual without
28 discontinuities. From a general theoretical point of view, however, the observed step-like behaviour
29 of the climate system is to be expected, as will be shown in the following paragraph.

6.2.3.2 *Behaviour of systems with non-linearities and feedback-loops*

In the natural sciences, a slow but nonetheless deep and fundamental revolution is taking place that started in the sixties in mathematics, physics and chemistry and gradually took over to all other disciplines of natural sciences. Its influence is spreading even to human sciences such as medicine, sociology and economy and important impacts on mental sciences as psychology can no longer be excluded. The mentioned revolution is centred around the seemingly contradictory notions of chaos and self-organisation that lead to a fundamental change of paradigms and offer a new understanding of nature.

Up to now, no general rules could be indicated that would guarantee that a given system will display chaos or self-organisation. However, necessary conditions enabling a system to make phase transitions into a chaotic or a self-organised state are circular causality and non-linearities. To illustrate this point, the possible fundamental behavioural change of a chemical system will be shown, resulting from non-linearities in the form of auto catalytic processes.

6.2.3.2.1 *A linear chemical system tends to the classical thermodynamic equilibrium*

One of the most obvious examples of a feedback-system is the basic chemical reaction that combines two educts A and B into a product AB. Because of the decay reaction due to the thermal vibrations AB disintegrates into A and B. Based on the bilinear kinetic equations, it can be shown that an asymptotically stable equilibrium concentration [AB] develops continuously being determined by the bilinear product $K[A][B]$. [A] and [B] are the concentrations of the educts that, in many industrial processes are held constant by continuous supply and K is the equilibrium constant, defined as the ratio of the kinetic reaction rate constant k for the combination-reaction ("forward reaction") and the respective constant k' for the decay reaction ("backward reaction" or feedback reaction). The system-inherent circular causality is schematically shown in figure 6.2.

A physical example of such a decay-dynamics is heat exchange between two masses with initially different temperatures. Also here, an asymptotically stable equilibrium state is continuously approximated that is defined by equal temperatures of both masses. Generally, such a stable equilibrium state is asymptotically approximated in every closed system and the thermodynamic equilibrium shows maximum entropy (maximum "disorder").

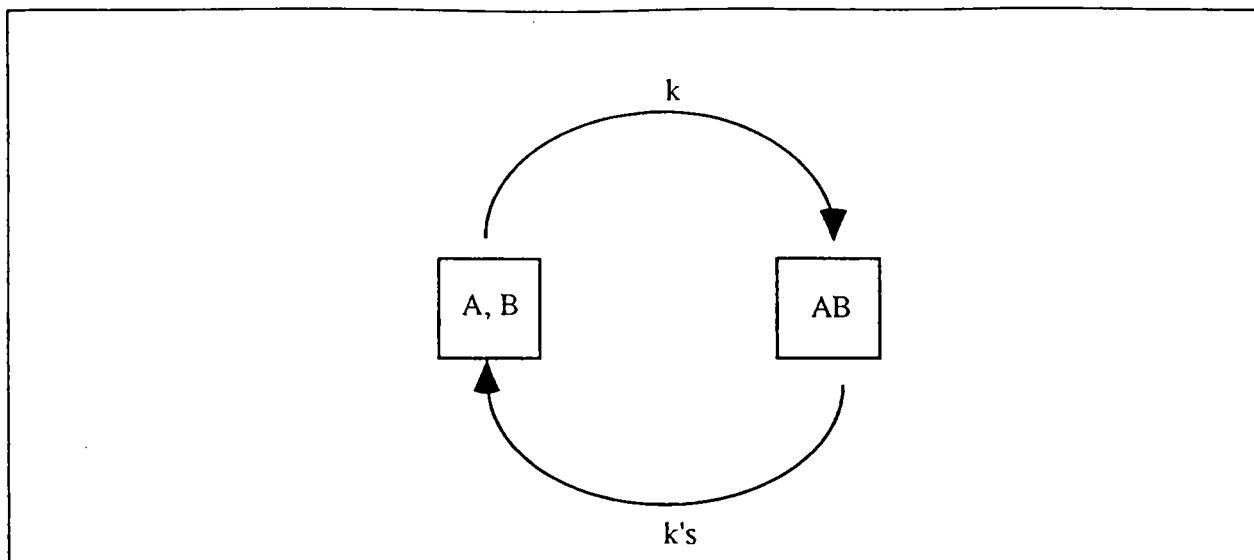


Figure 6.2: Circular causality in a bilinear system leading to a stable equilibrium concentration $[AB] = K [A][B]$ with an equilibrium constant $K = k/k'$ ($k, k' =$ reaction rate constant)

6.2.3.2.2 A non-linear chemical system can be found in different self-organised or chaotic states

If the two properties mentioned above, namely non-linearity and circular causality are combined, a new quality different from equilibrium can arise: self-organisation or chaos. In chemical systems, the most simple form of non-linearity comes from an auto catalytic reaction, where an intermediate product X is necessary for the synthesis of itself as shown in figure 6.3.

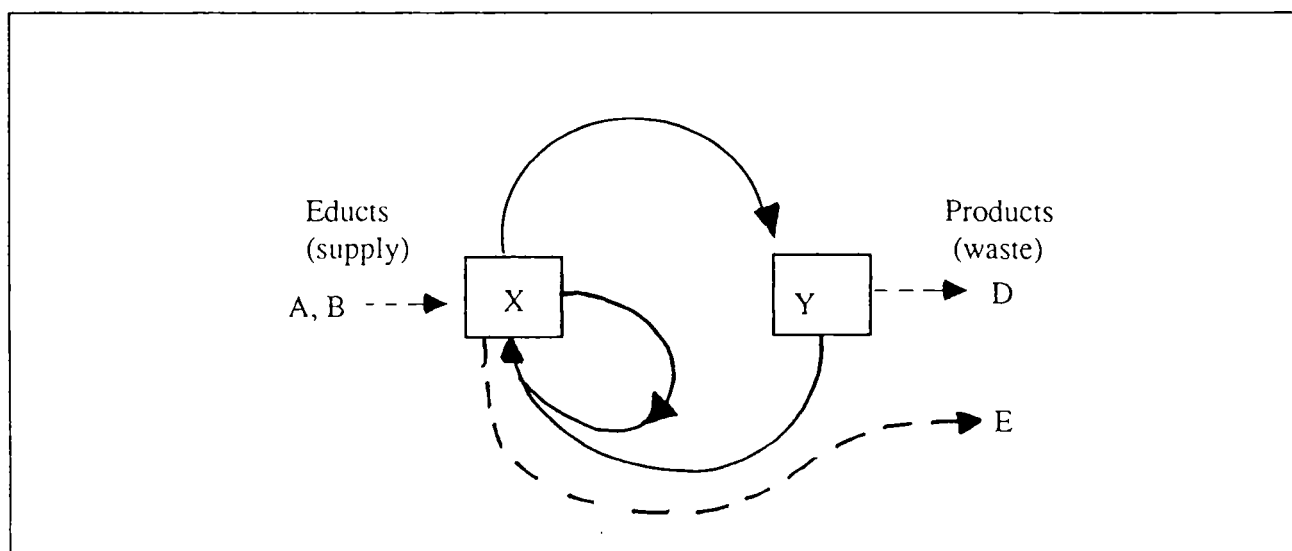


Figure 6.3: The most simple form of non-linearity in a chemical reaction arises from auto catalytic reactions.

The system is open: By a continuous supply of educts A and B, the intermediate products X and Y show patterns in time or space. The uninteresting products formed are normally called waste. The system is called dissipative.

6.2.3.2.3 *The possibly big effect caused by small stochastic fluctuations*

In the framework of the basic properties of non-linear systems with circular causality, especially the possibility of abrupt state changes, small stochastic fluctuations become important factors showing the time evolution of a system. As soon as the system approaches a critical value of a control parameter, an unpredictable fluctuation might be the cause triggering an abrupt phase transition into one of several possible nearby states. Even if all the critical values would be exactly known, neither the transition time nor the follow-up state could be predicted due to the uncertainty coming from stochastic fluctuations. Thus, in the optimal case of complete knowledge about the system, the spectrum of possible metastable states (scenarios) could be described, but no time evolution could be predicted.

6.2.3.3 *Different climate change scenarios to be considered*

The main characteristics of the global climate system is its structure consisting of many interlinked feedback-loops, many of which being highly non-linear. Especially the hydrological cycle shows strong non-linearities: exponential saturation pressure curve for water vapour versus temperature, phase change from water to snow or ice at 0°C leading to abrupt surface albedo increase, critical sea surface temperature of 27.5°C for dramatic increase of deep convection and thunderstorms etc. An important property of the climate system is the strong coupling between different regions of the globe by atmospheric or sea currents. Furthermore, different important delays complicate the dynamic response of the climate system. Examples are: heat capacity of the sea-surface layer (ca. 70 m deep), time for melting snow, ice etc.

A system with intensive non-linear feedback-loops is a good candidate for self-organisation and whence abrupt changes at critical values of control-parameters or even for chaotic behaviour above a certain threshold. As the past 200'000 years including the last two glacial times as well as the Eem interglacial show everywhere abrupt changes and climate instabilities, it is indeed a so far unsolved problem why the past 5% of this time, the Holocene, showed a practically stable climate. As long as this question cannot be answered, this comfortable climate stability must be considered as exceptional and probably fragile. The most natural behaviour to be expected is not a gradual warming but rather an abrupt phase change, a transition to another climate regime (i.e. the Eem regime with roughly 2K higher temperatures).

1 It turns out that scenarios can be revisited according to these emerging scientific insights. Here are
2 three possible scenarios that go to abrupt regional change from the "classical" scenario which is char-
3 acterised by gradual warming. Uncertainties are attached to these scenarios with reference to the rec-
4 onciliation framework (Table 6.4) shown in Section 1.
5

- 6 • The "*classical scenario*" with a gradual warming of 0.3 K per decade is not yet ruled out but has
7 to be considered as the exception rather than the rule. As it would be a reliable global long term
8 process with rather unpredictable but continuous regional evolutions, it would fall into the cate-
9 gory of "*weak uncertainty*".
- 10 • The "*abrupt global change*" scenario with a sudden important temperature increase within a
11 short period (1-10 years) seems to be a natural candidate based on theoretical reasons as well as
12 new paleo-climatological results. The time point where the abrupt change will take place as well
13 as the amplitude of the steps and the regional responses will be unknown, so leading to "*strong*
14 "*uncertainty*".
- 15 • The "*abrupt regional change*" scenario with sudden important climate changes in certain regions
16 is a possible combination of the above described scenarios. While the global average tempera-
17 ture increase would be rather continuous and reliable, it would be unknown which region will be
18 next for what change. We would face a "*globally weak but regionally strong uncertainty*".
19

20 These scenarios and attached uncertainties call for response strategies that are robust enough
21 against abrupt regional or global changes. These still are scenarios—and thus not yet probability dis-
22 tributions. Time evolution is not predicted. These views, therefore, emphasise the appropriateness of
23 the uncertainty vs. risk framework we choose to develop in Section 1.



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



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cc: SJK

*Rec'd
9/6/94
via fax
E/P*

MEMORANDUM

TO: Dr. Joseph Stiglitz
FROM: Dr. Erik Haites *Erik*
CC: Dr. Sally Kane
RE: Attached Materials
DATE: September 3, 1994

Here are the Work Plan from Montreal and the Work plan for Seoul. Unfortunately, we were not able to locate the list of lead authors and reviewers nominated by the U.S. - my sincere apologies for this inconvenience.

See you in Geneva.

Preliminary Agenda for Lead Authors Meeting

Seoul

September 6 - 8, 1993

Monday, September 6 - Chair: Dr. Hoesung Lee, Co-Chair, WG III

- | | |
|---------------|---|
| 8:00 - 8:30 | Registration |
| 8:30 - 9:00 | Welcome - Dr. Hoesung Lee, President, Korea Energy Economics Institute |
| 9:00 - 10:20 | IPCC Assessment Process: Dr. N. Sundararaman, Secretariat, IPCC
Dr. R. Odingo, Vice-Chair, WG III
Dr. T. Hanisch, Vice-Chair, WG III |
| | <ol style="list-style-type: none">1. History and function of the IPCC2. Scope of the Second Assessment Report3. Mandates of Working Groups I, II, and III4. Audiences for IPCC Second Assessment Report:<ul style="list-style-type: none">* Working Group reports and executive summaries* summaries for policymakers* synthesis report in response to INC mandate: Article 25. Philosophy of IPCC assessments, ie., peer-review process (expert and governmental), geographic representation, minority views6. Relationship of IPCC assessments to international ozone and biodiversity assessments |
| 10:20 - 10:40 | Refreshments |
| 10:40 - 12:00 | Logistical Arrangements for the Working Group III Report: Dr. Erik Haites, Head, Technical Support Unit, WG III |
| | <ol style="list-style-type: none">7. Roles, responsibilities, and deliverables of convening lead authors, lead authors, contributors, and working group chairs8. Timetable for Working Group III9. Length of report, chapters, and sections10. Procedures for review and acceptance of the report |
| 12:00 - 13:30 | Lunch |

- 13:30 - 15:00 Content of the Working Group III Report: Dr. Erik Haites
11. Content of the SAR and of individual chapters
 12. Division of the work among writing teams
 13. Overlaps among writing teams and among working groups
 14. Use of contributing authors
- 15:00 - 15:30 Refreshments
- 15:30 - 17:00 Content of Working Group III Report: Dr. Erik Haites
15. Working Group III workshops
 16. Common socio-economic and other parameters
- 18:00 - 19:00 Welcome Reception
Host: Dr. Hoesung Lee, President, Korea Energy Economics Institute

Tuesday, September 7

- 8:30 - 17:00 Separate meetings of writing teams
1. Select/confirm convening lead author
 2. Review scope of writing assignment to identify potential gaps and overlaps
 3. Discuss work assignments and schedule for writing team members
 4. Discuss potential contributing authors
 5. Discuss workshop content, format, and organization (if appropriate for the working team)

Wednesday, September 8 - Chair: Mr. James Bruce, Co-Chair, WG III

- 8:30 - 17:00 Plenary Meeting to Discuss Issues and Overlaps: Mr. James Bruce, Co-Chair, WG III
1. Questions raised by writing teams
 2. Review of schedule and workshops
 3. Liaison with Working Group I and II
 4. Next deadline

The Intergovernmental Panel on Climate Change (IPCC)

What is IPCC?

IPCC is an intergovernmental organization that assesses the current state of science - all types of science - as it related to climate change. IPCC does not actually do any science - it assesses what is known and provides advice and counsel to governments through its parent bodies, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

The history of IPCC

With the formation of the World Climate Programme after the first World Climate Conference in 1979, WMO and UNEP signalled their determination to pursue climate and climate change related studies. As interest and awareness of the issue of climate change heightened in the international community, it became clear that there was a need to make available to individual governments information on the subject of climate change so that they could formulate effective policies.

The idea of the IPCC was first suggested in 1987 and endorsed by the WMO Executive Council and the UNEP Governing Council at their meetings in 1988. The IPCC was established in 1988 and told to report to these governing bodies on the state of knowledge of climate change science and the environmental and socio-economic impacts of climate change. It was also tasked with formulating response strategies to deal with climate change.

What has IPCC achieved so far?

The first reports of the IPCC were issued in August 1990. The work of the Panel had been carried out by three working groups, one on science, one on impacts, and one on response strategies. Each working group produced a report which, together with an overview and a summary for policy makers, constituted the IPCC First Assessment Report. This report has now become a standard reference of work that is widely used by policy makers, scientists, and others.

Anticipating a need for the most current information on climate change to support the ongoing negotiations on the Framework Convention on Climate Change, the IPCC requested its working groups to update the First Assessment Report. The resulting IPCC Supplement was completed in February, 1992.

What is the IPCC doing now?

In November 1992, the IPCC was restructured into three new working groups, each of which was asked to provide input to a Second Assessment Report to be produced in 1995. Working

Group I on science was left unchanged and continues to build on the work described in the First Assessment Report. The new Working Group II will deal with assessing the impacts of climate change and developing response strategies. Working Group III is completely new and will deal with the socio-economics of climate change, the costs and benefits of mitigation and adaptation to climate change and to assess, if necessary develop, new emissions scenarios.

What is Working Group III doing?

Working Group III has a mandate to deal with issues related to climate change that cut across the mandates assigned to other working groups, and in particular with the sensitive and relatively new area of the socio-economics of climate change. The Working Group will also be examining and assessing the validity of various greenhouse gas emission scenarios. At the reorganizational meeting of the IPCC in November, 1992, Working Group III was asked to prepare technical assessments of the socio-economics of impacts, mitigation and adaptation to climate change and to consider and develop, as necessary, a range of future emissions scenarios for inclusion in the IPCC Second Assessment Report due in 1995.

How is Working Group III organized?

All member states of the World Meteorological Organization and the United Nations Environment Programme are eligible to participate in the work of the Working Group III. This participation could be in any and all activities outlined in the workplan and, in particular, could involve having individuals from those states participate in the authorship or review of the material prepared for the Second Assessment Report. This activity will be overseen and co-ordinated by the Working Group III Bureau, which consists of Co-chairs from Canada and Korea and Vice Chairs from Norway and Kenya.

Technical and secretariat support for the Working Group will be provided by Technical Support Unit (TSU) located in Environment Canada.

Work Programme of Working Group III

SCOPE OF WORK

It is proposed that the efforts of the newly reconstituted Working Group III of IPCC be carried out in the manner described in this work plan. Attached is a outline of the themes to be considered in the Working Group III Second Assessment Report (SAR).

The Working Group will, in accordance with its Terms of Reference, prepare a comprehensive technical assessment of the socio-economics of mitigation of climate change, the impacts of climate change, and adaptation to climate change over both the short and long term and at the regional and global levels. This contrasts with the work of Working Group II, which will be assessing the economic impacts on particular economic sectors at a more local level. Nevertheless, considerable collaboration between the two working groups will be necessary.

As reflected in United Nations General Assembly document A/AC.237/30 the chair of the Intergovernmental Negotiating Committee (INC) for the Framework Convention on Climate Change has requested that IPCC prepare, in time for the first meeting of the Conference of the Parties to the Convention (COP), "an evaluation of current scenarios of greenhouse gas¹ emissions and removals by sinks." The proposed time line addresses this request and assumes that the first meeting of the COP will take place in the spring of 1995. If this turns out not to be the case, the timing of activities shown that relate to the evaluation of scenarios would be adjusted accordingly. This element of the work is expected to build heavily on the work of the 1992 IPCC Update, which contained six greenhouse gas emissions scenarios. It is suggested that this work be carried out by examining the major assumptions made in developing the original scenarios and, based on whatever new information is available, assessing the validity and appropriateness of those assumptions and making recommendations on the need for updated or new scenarios. If it is agreed that new scenarios are needed, actions will have to be taken to develop them for the Second Assessment Report. The work on responding to the INC request will be closely coordinated with that on the same issue for the SAR by involving the same group of contributors. The IPCC Bureau is seeking clarification of the other elements of the INC's request, which raise cross-cutting issues which Working Group III may need to consider.

¹Throughout this document, the term "greenhouse gas" is as defined in Article 1 of the Framework Convention on Climate Change.

In evaluating scenarios and in developing its scientific and technical assessment, the Working Group proposes to undertake a number of specific activities, which are described in this work plan.

PRINCIPAL CONSIDERATIONS

The work of the Working Group will be carried out with the following considerations in mind:

- It will place the socio-economic perspectives of climate change in the context of sustainable development. In particular, and in accordance with the Framework Convention on Climate Change, the work of the Working Group will be comprehensive, cover all relevant sources, sinks, and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors.
- Institution and endogenous capacity building in developing countries will be integrated into the work programme.
- The work of the Working Group will not stand in isolation from other IPCC activities. Consultation and coordination with the activities of the other Working Groups will be carried out to the greatest extent possible.
- The work will, to the greatest extent possible, build on existing work, recognizing that the IPCC role is one of assessing existing knowledge for the Second Assessment Report.
- The activities of the Working Group will take into account the special situations of developing countries and economies in transition and will be carried out at a pace and be of a type that allows for the full involvement of these countries.
- The work will be carried out in as cost-efficient a manner as possible, bearing in mind the limited resource capacity of IPCC and all member countries. This implies close cooperation with other bodies working in the same fields in order to avoid duplication of effort.

ACTIVITIES OF THE WORKING GROUP

The Working Group will prepare a report comprising its contribution to the IPCC Second Assessment Report and containing a technical assessment of the state of knowledge of the socio-economics of climate change mitigation, adaptation, and impacts, taking into account the factors described in part (a) of the Terms of Reference of the Working Group. It is proposed that the structure of this report follow the proposed outline of the themes shown in Annex B.

The Working Group will also prepare a report, in time for the first meeting of the Conference of the Parties to the Convention, on the validity, appropriateness, and utility of existing net greenhouse gas emissions scenarios based on the factors described in part (b) of the Terms of Reference of the Working Group. An update of this report, including any new scenarios that it is agreed should be developed, will be included in the Group's contribution to the IPCC SAR.

The preparation of both reports would be carried out as follows, using the dates indicated in the time line in accordance with the procedures described in the IPCC proposal for procedures for preparation, review and adoption of IPCC reports:

- The Bureau of the Working Group will ask governments and participating organizations to identify experts in their countries who could be involved as part of teams of lead authors, contributors, and expert reviewers for each report. Governments will also be asked to identify IPCC contacts for the purpose of coordinating later review by their governments.
- The Bureau of the Working Group will ask governments to suggest themes, dates, and locations for IPCC workshops that could be held to review the scenarios and the scientific and technical work that is being assessed, bearing in mind the principal considerations noted above and the IPCC workshop policy. For reasons of economy and to avoid overlap and duplication, the Bureau will coordinate with other IPCC Working Groups and international organizations in conducting these workshops.
- Based on the suggestions of governments and participating organizations, the Bureau will meet with the Chair of IPCC and possibly with some of the experts identified, to decide on the detailed contents of each section of the reports, assign teams of lead authors for each section, and decide on which workshops should be held. The Bureau will also decide, from the perspective of Working Group III, whether IPCC co-sponsorship should be extended to other workshops, seminars, or meetings.

- Lead authors will undertake preparation of the first drafts of each section and submit them to the Co-chairs, bearing in mind the tasks and responsibilities identified for contributors and themselves.
- The first drafts will be circulated for peer review to the specialists. Referenced material will be made available by the Co-chairs, who will collect the comments of the reviewers and make them available to the lead authors. Lead authors will then revise the drafts and, if time permits in the schedule indicated in the time line, Co-chairs will circulate the revised drafts again for review.
- The revised drafts will be sent to governments and participating organizations for review.
- The summary for policy makers will be approved at a meeting of the Working Group in Plenary session and adopted by the Panel.

THEMES TO BE CONSIDERED IN THE WORKING GROUP III SECOND ASSESSMENT REPORT

PREFACE

The preface will outline the mandate and terms of reference of the working group, describe how it went about producing the report, what the intended audience of the report is, and the purposes for which the report should be used. The preface will note that none of the tasks shall involve the Working Group making policy judgements. Each chapter will also place the socioeconomic perspectives of climate change in the context of sustainable development. The working group should analyze the issues as broadly as possible recognizing the Rio Declaration on Environment and Development, Agenda 21 and in particular the Framework Convention on Climate Change, as adopted.

EXECUTIVE SUMMARY

SUMMARY FOR POLICY MAKERS

THE SECOND ASSESSMENT REPORT

The SAR consists of three parts. The first part addresses the scope of the assessment and the remaining two parts address the mandate of the Working Group.

PART I: SCOPE OF THE ASSESSMENT

This assessment will include, *inter alia*, the socio-economic perspectives of climate change, the nature of the interactions between economic activity and climate change, and emissions scenarios. The assessment will address the global nature of the problem, taking into account particularly the circumstances of countries vulnerable to the impacts of climate change and to the impacts of response measures. In addition, it will cover a scientific evaluation of the appropriateness of the methodologies used for the analysis, including the socio-economic assumptions underlying existing modelling frameworks, its relations to observable data such as national accounts figures (GDP). To fulfil the scope of the analysis, existing supplementary indicators (such as the Human Development Index developed by the UNDP) will be assessed.

PART II: THE SOCIO-ECONOMICS OF IMPACTS, ADAPTATION, AND MITIGATION OF CLIMATE CHANGE

The mandate of the Working Group states that it should undertake “Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, *inter alia*, consider the following topics: top-down and bottom-up economic modelling . . . ; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments” For each theme in this part, a key question to be answered that addresses this section of the mandate has been identified.

CHAPTER 1: SOCIO-ECONOMIC FRAMEWORK FOR DECISION-MAKING

Key question: How do we take socioeconomic factors into account when making decisions about the climate change issue? The issues addressed under this theme will include, *inter alia*:

Socio-economics of Climate Change in Relation to the Need for Sustainable Development

Decision-making under uncertainty:

- The socio-economic factors to be considered when making decisions in the short and long term.

Risk assessment including, *inter alia*, discussion of the following questions:

- What methods can be used to assess risk and what levels of confidence can be attached to such methods?
- What are the perceptions of and responses to risk?
- What are possible response measures?
- What are the risks of inaction and of undertaking “no-cost” or cost-effective “low-cost” response measures and of taking more far-reaching response measures? (This section should take into account sequential decision-making, portfolio analysis, benefits and costs of taking action early versus late, and the long-term implications of short-term decisions).

Methods and applications of cost-benefit analysis including, *inter alia*:

- Concepts such as opportunity costs, trade-offs, marginal costs and marginal benefits, limitations of cost-benefit analysis and consideration of alternative methodologies, and the value and importance of non-market factors such as biodiversity, long-term discounting, public perceptions, social well-being, thresholds, and irreversibilities.

Equity considerations including, *inter alia*:

- Varying contributions between regions for past emissions, the “free rider” problem, inter-regional and inter-generational equity, and the question of the time lags between the incurring of costs and the accruing of benefits.

The value of information including, *inter alia*, discussion of the following:

- Significant efforts are being undertaken every year on global climate research in the area of natural sciences. Where are the highest potential payoffs for likely future decisions? What are the most critical uncertainties, including scientific uncertainties? What kinds of research can reduce them and reinforce society’s ability to confront uncertainty? What is the value of this scientific research in terms of its ability to describe the linkages between the natural sciences and socio-economics? What are the predictable trends of scientific and technical progress in efficiency of use of different energy types with respect to carbon intensity and in the adaptation of species to new climatic situations?

Sociological considerations.

CHAPTER 2: ASSESSING THE BENEFITS OF RESPONSES TO CLIMATE CHANGE

Key question: What methods exist for assessing the economic and social benefits of action and inaction? The issues addressed under this theme will include, *inter alia*:

Methods for estimating benefits:

- The status-quo option. What would be the socio-economic impacts in the absence of any action to deal with the problem of increasing concentrations in the

atmosphere of greenhouse gases and aerosols? How would the benefits vary with different degrees and timing of actions to limit climate change?

- Methods based on market impacts. For example, adaptation through trade, market agents, migration of population, and economic activity.
- Methods based on non-market impacts such as ecological and social impacts.

Major issues in estimating benefits:

- An assessment of the state of knowledge related to issues involved in estimating benefits, including, *inter alia*; distinguishing between short-term and long-term impacts; the relationship of impacts to the degree, timing, and predictability of climate change; techniques for valuing impacts on ecosystems; hard-to-define values such as aesthetics, impacts on land use, impacts on biological diversity and other environmental problems and social well-being; and modelling limits dealing with thresholds, irreversibilities, and time horizons.

Methods for estimating the costs of human adaptation.

CHAPTER 3: EVALUATING THE COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS BY SOURCES AND REMOVAL BY SINKS

Key question: What are economic, social, and environmental contributions to understanding, both conceptually and empirically, the costs of mitigation of greenhouse gas emissions? The issues addressed under this theme will include, *inter alia*:

- Variables for measuring costs. A discussion of costs from a long-term perspective, including, *inter alia*, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.
- Assumptions in empirical analysis including, *inter alia*:
 - Modelling assumptions including uncertainties and ranges;
 - Technological change;
 - Macro-economic and demographic assumptions such as productivity growth, population and labour force change, and structural change in economies;

- Consumption patterns;
 - Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities, and exchange rates; and
 - Land use.
- Policy instruments for domestic and regional use including, *inter alia*:
 - Economic instruments such as taxes, subsidies, tradeable permits, tradeable absorption obligations, user charges, and deposit-refund schemes;
 - Regulatory instruments including technology-based and performance-based; and
 - Other instruments such as land use programmes and public awareness and education programmes.
 - Modelling methods: A description of various types of models (e.g., “top-down” and “bottom-up”) according to purpose, and a discussion of their relative strengths and weaknesses, including, *inter alia*, a discussion of data limitations and limitations of model applications, the reasons for differences in the predictions made by them and ways to evaluate those results, and the integration of modelling techniques (e.g., bottom-up studies of new technologies). The appropriateness of the modelling methods should be discussed in relation to the problems of developing countries and should reflect the concerns and special conditions of developing countries. The models should include as many different policy instruments as possible. Possible other issues include dynamic versus static models, econometric versus parametric models, perfect versus limited foresight in models, the treatment of international trade, model time horizons, and how various modelling techniques could be integrated. Different policy options will be used to derive model outputs.
 - Model comparisons: A comparison of results including, *inter alia*, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries, and a survey of the degree of dependency of countries on the production, exportation, and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

- Major issues of cost estimation: Potential topics include, *inter alia*, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.
- Topics for future work: A discussion of the types of future research needed such as the integration of bottom-up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

CHAPTER 4: GENERIC ASSESSMENT OF RESPONSE OPTIONS

Key question: What methods exist for assessing the net costs and effectiveness of different response options in a comprehensive manner?

The discussion of cost evaluation in each of these sections should incorporate a discussion of net costs and should include complementary socio-economic effects, both negative and positive, on such elements as GDP, employment levels, the balance of trade, economic structure, and the environment. The issues addressed under this theme will include, *inter alia*:

- Adaptation options: A discussion of different options for developed countries, developing countries, and those with special circumstances (e.g., low-lying, arid, and countries in transition).
- Mitigation options: A discussion of mitigation measures which should reflect, for example, the concept of comprehensiveness (all greenhouse gases, sinks, and sectors), including, *inter alia*, reducing emissions by correcting market and government policy shortcomings, eliminating subsidies and barriers, dissemination of information and technology cooperation, and introducing economic instruments.
- Methods for assessing the effectiveness of options including, *inter alia*, the use of models and the extent to which models incorporate the full range of options and conditions.
- Comparison within and between mitigation and adaptation response options. The comparison should include, *inter alia*, their cost-effectiveness, their influence on innovation and promoting environmentally sound technologies, their influence on

other environmental matters, their ease of administration, monitoring, and enforcement, their capacities to cope with uncertainties, their data requirements, and equity and sustainable development considerations.

- Technological change. A discussion of the factors determining technological change as a driving force for, as well as a way to control net greenhouse gas emissions (e.g., renewable energy, low-energy systems, carbon sequestration, etc.), taking into account the penetration, diffusion, and transfer of technology and the different dynamics in developed and developing countries; and which of these factors can be influenced and how.
- Internationally coordinated instruments. A discussion of mechanisms such as “joint implementation,” carbon leakages (shifts of carbon-intensive activities) linked to demographics, consumption patterns, and economic growth of industrialized and developing countries, assistance and trade aspects, and the possibilities and difficulties of internationally coordinated instruments.

PART III: EMISSIONS SCENARIOS

CHAPTER 5: CONSIDERATIONS OF CONSISTENT SCENARIOS

The mandate of the Working Group states that it “should consider . . . a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections.” With this in mind, the key question to be answered is, “Which issues and uncertainties about key variables may critically affect future net greenhouse gas emissions and aerosol concentrations?” The issues addressed under this theme will include, *inter alia*:

- Types of models for scenario development and their application.
- The assumptions made in developing existing scenarios. A discussion of the key assumptions concerning, *inter alia*, economic growth, demographics, consumption patterns, technological change, energy prices and supply, international trade flows, distributional issues, social change, sustainable development, land use, and non-greenhouse gas environmental constraints such as acid rain.
- The relative importance and sensitivity of different variables in determining future emissions and sinks.
- The relationships among key variables.

- The sensitivity of these variables, most notably to government actions.
- The relationship of scenarios to the emissions inventory methodology developed by Working Group I. A number of country studies are being completed and could make a useful contribution to scenario analysis.
- The degree of uncertainty, including, *inter alia*, a discussion of the following questions:
 - What are the gaps and uncertainties in available knowledge about these factors and their influences on emissions?
 - What does the extent of this uncertainty tell us about the validity of current scenarios? How do existing IPCC scenarios compare with other existing scenarios? Are new scenarios required?
 - What are likely to be the impacts of this uncertainty on short- and long-term future emission scenarios?
- Model structures for analysis of scenarios, including, *inter alia*, a discussion of the following questions:
 - How useful are current models in terms of their regional detail, solution algorithms, and data?
 - What are the characteristics of current models?
 - What is the sensitivity and flexibility of models to technical and structural assumptions?
- The appropriate uses, capabilities, and limitations of emissions scenarios in scientific assessment and policy-making.
- An assessment of the need for future work on scenarios to serve the needs of climate modelling, planning of response measures, and provision of information to the Conference of Parties to the Framework Convention on Climate Change.

Tasks and Responsibilities for Lead Authors, Contributors, and Expert Reviewers of IPCC Reports and IPCC Government Contacts

Lead Authors

Functions: To produce designated sections addressing items of the work programme on the basis of the best scientific and technical information available.

Comment: The essence of the lead authors' task is synthesis of material drawn from the peer reviewed literature, generated at workshops or submitted by contributors. Lead authors may not necessarily write original text themselves, but they must have the proven technical ability to develop text that is scientifically sound and that faithfully represents, to the extent that this is possible, contributions by a wide variety of experts. the ability to work to deadlines is also a necessary practical requirement.

Lead authors will typically work as small groups which have responsibility for ensuring that the various components of their sections are brought together on time, are of uniformly high quality and conform to any overall standards of style set for the document as a whole.

The task of lead authors is a demanding one and in recognition of this their names should appear prominently in the final report. During the final stages of report preparation, when the workload is often particularly heavy and when lead authors are heavily dependent upon each other to read and edit material, and to agree to changes promptly, it is essential that the work should be accorded the highest priority.

Principles Governing IPCC Work require Lead Authors to record views which cannot be reconciled with a consensus view but which are nonetheless scientifically valid.

Lead authors may convene meetings with contributors, as appropriate, in their preparations of their sections and to suggest any workshops in their relevant area to the Working Group co-chairs.

Convening Lead Authors

In addition to the duties of a lead author, the convening lead author coordinates the efforts of the writing team to ensure that all issues are

comprehensively addressed and that reports and revisions are completed on schedule.

Contributors

Function: To prepare technical information in the form of text, graphs or data for assimilation by the lead authors into the draft section.

Comment: Input from a wide range of contributors is a key element in the success of IPCC assessments, and the names of all contributors should be acknowledged in the reports. Contributions are sometimes solicited by Lead Authors but unprompted contributions are positively encouraged.

Contributed material may be edited, merged and if necessary, amended, in the course of developing the overall draft text.

Expert Reviewers

Function: To comment on the accuracy and completeness of the scientific/technical content and the overall scientific/technical balance of drafts.

Comments: Expert reviewers will comment on the text according to their own knowledge and experience. They may be nominated by governments, national and international organizations, Working Group Bureaus, Lead Authors, and contributors.

Government Review

Function: To comment on the accuracy and completeness of the scientific/technical content and the overall scientific/technical balance of drafts.

Comment: Government review will typically be carried out within and between a number of Departments and Ministries. Countries may convene their own seminars and workshops to review draft reports and advise on comments. For administrative convenience, countries should nominate a single IPCC Government Contact.

Procedures for Preparation, Review, and Acceptance, of IPCC Reports

Organization of Work

Preparation of the first draft of a report should be undertaken by lead authors identified by the relevant Working Group bureau from those experts cited in the lists provided by all countries and participating organizations, with due consideration being given to those known through their publication or work. Insofar as practicable, the composition of the group of lead authors for a section of a report shall reflect fair balance among different points of view that can reasonably be anticipated by the Working Group bureau, and should include at least one expert from a developing country.

At the earliest opportunity, Working Groups should inform all IPCC countries and participating organizations about who the lead authors are and the areas they are covering. Experts who wish to contribute material for consideration in the first draft should submit it directly to the lead authors. Contributions should be in the form of text specifically written for the draft report and supported as far as possible with references from the peer-reviewed and internationally-available literature, and with pre-prints of any unpublished material cited.

Lead authors will work on the basis of these IPCC contributions, the peer-reviewed and internationally-available literature including scientific and technical publications prepared by national governments and scientific bodies, the latest reports from researchers that can be made available in pre-print form for IPCC review, and IPCC supporting material.

In preparing the first draft, and at subsequent stages of review, lead authors should clearly identify disparities of view for which there is significant scientific or technical support, together with the relevant arguments.

Review by Experts

First draft reports should be circulated by Working Group co-chairs for review by experts. The review circulation should include:

- specialists who have significant publications in particular areas;
- specialists on the IPCC lists maintained by the Working Group co-chairs;
- IPCC countries and participating organizations;
- specialist reviewers nominated by appropriate international scientific and technical organizations (eg. WMO, UNEP, ICSU, Third World Academy of Science, FAO, IOC, World Bank, Regional Development Banks, OECD).

The Working Group co-chairs should make available to reviewers on request all material referenced in the document being reviewed which is not available in the international published literature.

Comments by reviewers should be made available to the appropriate lead authors. Working Group co-chairs should arrange for a full record to be kept of all comments received and, upon request, the comments should be made available to contributors and reviewers.

Lead authors, in conjunction with Working Group co-chairs, are encouraged to supplement the draft revision process by organizing a wider meeting with principal contributors and reviewers, if time and funding permit, to pay special attention to particular points of assessment or areas of major differences.

The time schedule allowed for return of review comments will be constrained by the IPCC work schedule, but normally should not be less than six weeks, except when special circumstances permit only one month. More time may be required for some material. If time allows, a revised draft incorporating comments, together with any appropriate summary, should be circulated again for review by experts.

Review by Governments

A revised draft should be distributed by Working Group co-chairs to governments through the designated IPCC government contacts, and to all the original contributors and reviewers.

Governments should send one integrated set of comments for each Working Group report to the appropriate Working Group co-chairs through their IPCC government contacts. they may wish to organize their own mechanisms for consulting experts in preparing their responses.

To facilitate government review, non-government reviewers should send their further comments to Working Group co-chairs with a copy of their appropriate government IPCC contact.

Contributors and reviewers should make full use of the draft and revised report review procedures to pursue the incorporation of their contributions in the final report.

The time available for return of government reviews should not be less than six weeks.

Preparation of a final draft report for submission to Working Group Plenary should be undertaken by lead authors, and Working Group co-chairs as appropriate. If necessary, and timing and funding permit, a wider meeting with principal contributors and reviewers is encouraged to pay special attention to particular points of assessment or areas of major differences. It is important that reports describe different (possibly controversial) scientific or technical views on a subject, particularly if they are relevant to the political debate. The final draft should credit all lead authors, contributors, expert reviewers, and country reviewers by name and affiliation.

Acceptance of the Report

A final draft taking into account country comments should be distributed to all IPCC countries and participating organizations not less than three weeks prior to a Working Group Plenary meeting called to accept the report and transmit it to the IPCC Plenary. It is for the Working Group co-chairs to assess the time necessary for completing action in a timely manner, according to the complexity of the task and to the amount of work already in hand within the IPCC or other bodies already working in the field.

P938005\procedure.rep

Proposed Writing Teams and Assignments for the Working Group III Second Assessment Report

The Working Group III Bureau has attempted to assign lead authors to writing teams by matching the author's expertise to the scope of the writing assignment. This is not an exact process, most authors have expertise related to several of the writing assignments and the Bureau's knowledge of each of the author's credentials is less than perfect.

The Bureau is open to transferring lead authors to writing teams which they feel better suit their qualifications. If you wish to transfer to another writing team, please contact Erik Haites, Head, Technical Support Unit, Working Group III at tel: +416-369-0900 or fax: +416-369-0922 as soon as possible. Your request will be addressed during the Lead Authors meeting in Seoul.

A convening Lead Author has been proposed by the Working Group III Bureau for each writing team. Each writing team will be asked to select/confirm a convening lead author during its meeting on September 7.

**PROPOSED WRITING ASSIGNMENTS FOR
THE WORKING GROUP III
SECOND ASSESSMENT REPORT
(Draft, August 17, 1993)**

PREFACE Working Group III Bureau

The preface will outline the mandate and terms of reference of the working group, describe how it went about producing the report, what the intended audience of the report is, and the purposes for which the report should be used. The preface will note that none of the tasks shall involve the Working Group making policy judgements. Each chapter will also place the socioeconomic perspectives of climate change in the context of sustainable development. The working group should analyze the issues as broadly as possible recognizing the Rio Declaration on Environment and Development, Agenda 21 and in particular the Framework Convention on Climate Change, as adopted.

EXECUTIVE SUMMARY Working Group III Bureau for review by all lead authors

SUMMARY FOR POLICY MAKERS Working Group III Bureau for review by all lead authors

PART I: SCOPE OF THE ASSESSMENT

Writing Team 1:	SCOPE OF THE ASSESSMENT
C	*
	Jose Goldemberg, Brazil
	Udo Simonis, Germany
	*
	Joe Stiglitz, U.S.A.
	*
	Akihiro Amano, Japan
	*
	Xie Shaoxiong, China
	*
	Ruby Saha, Mauritius

Part I will place global warming in a sustainable development context. This assessment will include, *inter alia*, the socio-economic perspectives of climate change, the nature of the interactions between economic activity and climate change, and emissions scenarios. The assessment will address the global nature

of the problem, taking into account particularly the circumstances of countries vulnerable to the impacts of climate change and to the impacts of response measures. In addition, it will cover a scientific evaluation of the appropriateness of the methodologies used for the analysis, including the socio-economic assumptions underlying existing modelling frameworks, its relations to observable data such as national accounts figures (GDP). To fulfil the scope of the analysis, existing supplementary indicators will be assessed.

Resource limitation that may affect global warming (eg. Fossil fuel reserves) or emission reduction options (eg. Hydro-electric potential, biomass fuel production) will be reviewed.

PART II: THE SOCIO-ECONOMICS OF IMPACTS, ADAPTATION, AND MITIGATION OF CLIMATE CHANGE

The mandate of the Working Group states that it should undertake “Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, *inter alia*, consider the following topics: top-down and bottom-up economic modelling . . . ; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments” For each theme in this part, a key question to be answered that addresses this section of the mandate has been identified.

CHAPTER 1: SOCIO-ECONOMIC FRAMEWORK FOR DECISION-MAKING

Note: CHAPTER 1 is spread across THREE writing teams as indicated below.

Key question: How do we take socioeconomic factors into account when making decisions about the climate change issue? The issues addressed under this theme will include, *inter alia*:

Writing Team 2:	DECISION-MAKING FRAMEWORK
C	*
	Jyoti Parikh, India
	*
	Kenneth Arrow, U.S.A.
	*
	Gonzague Pillet, Switzerland
	???, developing country
	???, economy in transition

Socio-economics of Climate Change in Relation to the Need for Sustainable Development

Decision-making under uncertainty:

- The socio-economic factors to be considered when making decisions in the short and long term.
- Factoring the risks of increased frequency of extreme events and irreversibilities into decisions.

Risk assessment including, *inter alia*, discussion of the following questions:

- What methods can be used to assess risk and what levels of confidence can be attached to such methods?
- What are the perceptions of and responses to risk?
- What are possible response measures?
- What are the risks of inaction and of undertaking “no-cost” or cost-effective “low-cost” response measures and of taking more far-reaching response measures? (This section should take into account sequential decision-making, portfolio analysis, benefits and costs of taking action early versus late, and the long-term implications of short-term decisions).

The value of information including, *inter alia*, discussion of the following:

- Significant efforts are being undertaken every year on global climate research in the area of natural sciences. Where are the highest potential payoffs for likely future decisions? What are the most critical uncertainties, including scientific uncertainties? What kinds of research can reduce them and reinforce society’s ability to confront uncertainty? What is the value of this scientific research in terms of its ability to describe the linkages between the natural sciences and socio-economics? What are the predictable trends of scientific and technical progress in efficiency of use of different energy types with respect to carbon intensity and in the adaptation of species to new climatic situations?

**Writing Team 3: APPLICABILITY OF BENEFIT-COST ANALYSIS
 TO CLIMATE CHANGE**

**C * Mohan Munasinghe, World Bank
 Michael Hoel, Norway
 Carl-Christian von Weizsacker, Germany
 ???, developing country
 ???, Korea**

Can cost-benefit analysis be applied in a manner consistent with sustainable development?

Methods and applications of cost-benefit analysis including, *inter alia*:

- Concepts such as opportunity costs, trade-offs, marginal costs and marginal benefits, limitations of cost-benefit analysis and consideration of alternative methodologies, and the value and importance of non-market factors such as biodiversity, long-term discounting, public perceptions, social well-being, increased frequency of extreme events, thresholds, and irreversibilities.

Writing Team 4: EQUITY AND SOCIAL CONSIDERATIONS

**C * Harold Jacobson, U.S.A.
 * Karl Goran-Maler, Sweden
 Michael Grubb, U.K.
 * Calestous Juma, Kenya
 Tariq Banuri or Syed Qutub, Pakistan**

Equity considerations including, *inter alia*:

- Varying contributions between regions for past emissions, the “free rider” problem, inter-regional and inter-generational equity, and the question of the time lags between the incurring of costs and the accruing of benefits.

Sociological considerations.

Note: The assessment of these topics should establish the limits of scientific analysis and identify the role of values.

CHAPTER 2: ASSESSING THE BENEFITS OF RESPONSES TO CLIMATE CHANGE

Key question: What methods exist for assessing the economic and social benefits of action and inaction? The issues addressed under this theme will include, *inter alia*:

Writing Team 5: BENEFITS OF RESPONSES TO CLIMATE CHANGE

C	*	David Pearce, U.K.	
	*	Kerry Smith, U.S.A.	
	*	William Cline, U.S.A.	
	*	R.K. Pachauri, India	WG II
	*	Pier Vellinga, Netherlands	WG II

Methods for estimating benefits:

- The status-quo option. What would be the socio-economic impacts in the absence of any action to deal with the problem of increasing concentrations in the atmosphere of greenhouse gases and aerosols? How would the benefits vary with different degrees and timing of actions to limit climate change?
- Methods based on market impacts. For example, adaptation through trade, market agents, migration of population, and economic activity.
- Methods based on non-market impacts such as ecological and social impacts.

Major issues in estimating benefits:

- An assessment of the state of knowledge related to issues involved in estimating benefits, including, *inter alia*, distinguishing between short-term and long-term impacts; the relationship of impacts to the degree, timing, and predictability of climate change; techniques for valuing impacts on ecosystems; hard-to-define values such as aesthetics, impacts on land use, impacts on biological diversity and other environmental problems and social well-being; and modelling limits dealing with thresholds, increased frequency of extreme events, irreversibilities, and time horizons.

Methods for estimating the costs of human adaptation.

CHAPTER 3: EVALUATING THE COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS BY SOURCES AND REMOVAL BY SINKS

Note: CHAPTER 3 is spread across THREE writing teams as indicated below.

Key question: What are economic, social, and environmental contributions to understanding, both conceptually and empirically, the costs of mitigation of greenhouse gas emissions? The issues addressed under this theme will include, *inter alia*:

**Writing Team 6: COSTS OF MITIGATION OF GREENHOUSE GAS
EMISSIONS TO IN THE SHORT RUN**

- | | | | |
|---|---|---------------------------------|-------|
| C | * | John Robinson, Canada | |
| | * | Olivier Godard, France | |
| | * | Thomas Johansson, Sweden | WG II |
| | | Ogunlade Davidson, Sierra Leone | |
| | | William Nordhaus, U.S.A. | |
| | * | Plino Nastari, Brazil | |

Note: This team will focus on issue related to estimating costs of mitigation in the short run (roughly 10 to 25 years). In particular, it will focus on comparison of top-down and bottom-up modelling approaches and what can be learned from each.

Variables for measuring costs.

- A discussion of costs from a long-term perspective, including, *inter alia*, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.

Assumptions in empirical analysis including, *inter alia*:

- Modelling assumptions including uncertainties and ranges;
- Technological change;

- Macro-economic and demographic assumptions such as productivity growth, population and labour force change, and structural change in economies;
- Consumption patterns;
- Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities, and exchange rates; and
- Land use.

Modelling methods

- A description of various types of models (e.g., “top-down” and “bottom-up”) according to purpose, and a discussion of their relative strengths and weaknesses, including, *inter alia*, a discussion of data limitations and limitations of model applications, the reasons for differences in the predictions made by them and ways to evaluate those results, and the integration of modelling techniques (e.g., bottom-up studies of new technologies). The appropriateness of the modelling methods should be discussed in relation to the problems of developing countries and should reflect the concerns and special conditions of developing countries. The models should include as many different policy instruments as possible. Possible other issues include dynamic versus static models, econometric versus parametric models, perfect versus limited foresight in models, the treatment of international trade, model time horizons, and how various modelling techniques could be integrated. Different policy options will be used to derive model outputs.

Model comparisons

- A comparison of results including, *inter alia*, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries, and a survey of the degree of dependency of countries on the production, exportation, and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

from Chapter 2

Major issues of cost estimation

- Potential topics include, *inter alia*, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.

Topics for future work

- A discussion of the types of future research needed such as the integration of bottom-up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

Writing Team 7: COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS IN THE LONG RUN

- C * Jean-Charles Hourcade, France
Andrew Dean or Peter Sturm, OECD
- * Richard Richels, U.S.A.
- * Dale Jorgenson, U.S.A.
- * Angelica Tudini, Italy
- ???, economy in transition
- ???, Korea

Note: This team will focus on issue related to estimating cost of mitigation in the long-run (25 to 100 years or more). In particular it will focus on technological change, its impact on mitigation costs, and methods/costs of stimulating technological change.

It will also deal with the question of the optimal trajectory to stabilization of atmospheric concentrations of greenhouse gases.

Variables for measuring costs.

- A discussion of costs from a long-term perspective, including, *inter alia*, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.

Assumptions in empirical analysis including, *inter alia*:

- Modelling assumptions including uncertainties and ranges;
- Technological change;
- Macro-economic and demographic assumptions such as productivity growth, population and labour force change, and structural change in economies;
- Consumption patterns;
- Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities, and exchange rates; and
- Land use.

Model comparisons

- A comparison of results including, *inter alia*, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries, and a survey of the degree of dependency of countries on the production, exportation, and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

from Chapter 2

Major issues of cost estimation

- Potential topics include, *inter alia*, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.

from Chapter 4

- Technological change. A discussion of the factors determining technological change as a driving force for, as well as a way to control net greenhouse gas emissions (e.g., renewable energy, low-energy systems, carbon sequestration, etc.), taking into

account the penetration, diffusion, and transfer of technology and the different dynamics in developed and developing countries; and which of these factors can be influenced and how.

Topics for future work

- A discussion of the types of future research needed such as the integration of bottom-up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

Writing Team 8: POLICY INSTRUMENTS

- C * Brian Fisher, Australia**
Scott Barrett, U.K.
- * Peter Bohm, Sweden**
*** Anwar Shah, World Bank**
Tomasz Zylicz, Poland
*** J. Mubazi, Uganda**

Policy instruments for domestic and regional use including, *inter alia*:

- Economic instruments such as taxes, subsidies, tradeable permits, tradeable absorption obligations, user charges, and deposit-refund schemes;
- Regulatory instruments including technology-based and performance-based; and
- Other instruments such as land use programmes and public awareness and education programmes.

from Chapter 4

- Internationally coordinated instruments. A discussion of mechanisms such as “joint implementation,” carbon leakages (shifts of carbon-intensive activities) linked to demographics, consumption patterns, and economic growth of industrialized and developing countries, assistance and trade aspects, and the possibilities and difficulties of internationally coordinated instruments.

Note This team should also consider the issues related to structure of the carbon tax raised by Peter Read of New Zealand.

CHAPTER 4: GENERIC ASSESSMENT OF RESPONSE OPTIONS

Key question: What methods exist for assessing the net costs and effectiveness of different response options in a comprehensive manner?

Writing Team 9: GENERIC ASSESSMENT OF RESPONSE OPTIONS

- | | | |
|----------|----------|--|
| C | * | Robert Stavins, U.S.A. |
| | * | R.S. Maya, Zimbabwe |
| | * | Catrinus Jepma, Netherlands |
| | | Mohammed Asaduzzaman, Bangladesh |
| | * | Irving Mintzer, Stockholm Environment Institute |

The discussion of cost evaluation in each of these sections should incorporate a discussion of net costs and should include complementary socio-economic effects, both negative and positive, on such elements as GDP, employment levels, the balance of trade, economic structure, and the environment. The issues addressed under this theme will include, *inter alia*:

- **Adaptation options:** A discussion of different options for developed countries, developing countries, and those with special circumstances (e.g., low-lying, arid, and countries in transition).
- **Mitigation options:** A discussion of mitigation measures which should reflect, for example, the concept of comprehensiveness (all greenhouse gases, sinks, and sectors), including, *inter alia*, reducing emissions by correcting market and government policy shortcomings, eliminating subsidies and barriers, dissemination of information and technology cooperation, and introducing economic instruments.
- **Methods for assessing the effectiveness of options** including, *inter alia*, the use of models and the extent to which models incorporate the full range of options and conditions.
- **Comparison within and between mitigation and adaptation response options.** The comparison should include, *inter alia*, their cost-effectiveness, their influence on innovation and promoting

environmentally sound technologies, their influence on other environmental matters, their ease of administration, monitoring, and enforcement, their capacities to cope with uncertainties, their data requirements, and equity and sustainable development considerations.

PART III: EMISSIONS SCENARIOS

CHAPTER 5: CONSIDERATIONS OF CONSISTENT SCENARIOS

Writing Team 10: EMISSIONS SCENARIOS

C	*	Joseph Alcamo, Netherlands	
	*	Tsuneyuki Morita, Japan	
	*	Majid Al-Munif, Saudi Arabia	
	*	James (Jae) Edmonds, U.S.A.	WG II
	*	Zhou Dadi, China	
		Amulya Reddy, India	
	*	Aca Sugandhy, Indonesia	

The mandate of the Working Group states that it “should consider . . . a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections.” With this in mind, the key question to be answered is, “Which issues and uncertainties about key variables may critically affect future net greenhouse gas emissions and aerosol concentrations?” The issues addressed under this theme will include, *inter alia*:

- Types of models for scenario development and their application.
- The assumptions made in developing existing scenarios. A discussion of the key assumptions concerning, *inter alia*, economic growth, demographics, consumption patterns, technological change, energy prices and supply, international trade flows, distributional issues, social change, sustainable development, land use, and non-greenhouse gas environmental constraints such as acid rain.
- The relative importance and sensitivity of different variables in determining future emissions and sinks.
- The relationships among key variables.
- The sensitivity of these variables, most notably to government actions.

- The relationship of scenarios to the emissions inventory methodology developed by Working Group I. A number of country studies are being completed and could make a useful contribution to scenario analysis.
- The degree of uncertainty, including, *inter alia*, a discussion of the following questions:
 - What are the gaps and uncertainties in available knowledge about these factors and their influences on emissions?
 - What does the extent of this uncertainty tell us about the validity of current scenarios? How do existing IPCC scenarios compare with other existing scenarios? Are new scenarios required?
 - What are likely to be the impacts of this uncertainty on short- and long-term future emission scenarios?
- Model structures for analysis of scenarios, including, *inter alia*, a discussion of the following questions:
 - How useful are current models in terms of their regional detail, solution algorithms, and data?
 - What are the characteristics of current models?
 - What is the sensitivity and flexibility of models to technical and structural assumptions?
- The appropriate uses, capabilities, and limitations of emissions scenarios in scientific assessment and policy-making.
- An assessment of the need for future work on scenarios to serve the needs of climate modelling, planning of response measures, and provision of information to the Conference of Parties to the Framework Convention on Climate Change.

Schedule for the Work of Working Group III

Revised July 30, 1993

Aug. 15, 1993	Final submissions of lead author nominees and final adjustments to writing teams for WG III.
Aug. 16, 1993	WG III Bureau finalizes the list of lead authors.
Aug. 30 to Sept. 3, 1993 Geneva	WG III representatives attend WG II lead authors meeting.
Sept. 6-8, 1993 Seoul	WG III lead authors meeting.
<i>Sept. 1993 to Feb. 1994</i>	<i>Lead authors for review of current emissions scenarios prepare first draft of their chapter.</i>
Sept. 1993 to Aug. 1994	Workshops are held and lead authors prepare first drafts of Second Assessment Report (SAR) chapters.
Dec. 6-8, 1993 Shepperton, U.K.	WG III bureau participates in proposed WG I Bureau meeting to review progress of collaborative efforts.
<i>Feb. 3, 1994 Geneva</i>	<i>Expanded WG III Bureau meeting to review evaluation of current emissions scenarios.</i>
Feb. 4-5, 1994 Geneva	IPCC Bureau meets to review collaborative mechanisms and to monitor progress of IPCC work.
<i>Mar. 1, 1994</i>	<i>Draft evaluation of current emissions scenarios completed and distributed for peer review.</i>
<i>Mar. 31, 1994</i>	<i>Peer review comments on draft evaluation of current emissions scenarios received. Experts prepare the first draft of material for the COP.</i>

Note: Items in italics relate to the review of emissions scenarios. Joint meetings of the Working Group II and Working Group III Bureaus will be scheduled at appropriate times.

<i>April 1994 Fortaleza, Brazil</i>	<i>Expanded WG III Bureau meeting to review draft material for the COP. Workshop on emissions scenarios.</i>
<i>April 11-15, 1994 Fortaleza, Brazil</i>	WG III participates in proposed joint workshop with WG I and WG II on stabilization of atmospheric concentrations, regional climate change scenarios and implications for impacts assessments.
<i>May 1994</i>	<i>Draft evaluation of current emissions scenarios for COP circulated for review by countries and organizations.</i>
<i>July 1994</i>	<i>Draft evaluation of current emissions scenarios for COP revised in light of government comments.</i>
<i>Aug. 31, 1994</i>	Drafts of chapters for the SAR sent to the WG III Bureau by writing teams for preparation by Bureau of Executive Summary and Policy Makers Summary.
<i>Sept. 5, 1994 Geneva</i>	<i>WG III Bureau Meeting to approve emission scenario report for COP.</i>
<i>Sept. 6-7, 1994 Geneva</i>	<i>WG III Plenary to approve emission scenario report for COP.</i>
<i>Sept. 8-10, 1994 Geneva</i>	Lead authors meeting to discuss draft chapters, overlaps, and key points for summaries.
<i>Oct. 1994</i>	Co-chairs distribute first draft of SAR chapters, draft Executive Summary and Policy Makers Summary for peer review.
<i>Nov. 10 -12, 1994 Nairobi</i>	<i>IPCC Plenary approves evaluation of current emissions scenarios for COP.</i>
<i>Dec. 1994 to Feb. 1995</i>	Lead authors and WG III Bureau revise SAR based on peer review comments.
<i>Jan. 1995</i>	Workshop on Article 2 of the Framework Convention on Climate Change.
<i>End Feb. 1995</i>	Revised draft of SAR circulated for review by countries and organizations.

Note: Items in italics relate to the review of emissions scenarios. Joint meetings of the Working Group II and Working Group III Bureaus will be scheduled at appropriate times.

Apr. to May, 1995	Lead authors and WG III Bureau prepare final draft of SAR including the Executive Summary and Policy Makers Summary based on comments from IPCC countries and organizations.
May 1995	WG III Bureau meets to approve SAR chapters, Executive Summary and Policy Makers Summary.
June 1995	WG III Plenary considers SAR chapters and approves Executive Summary and Policy Makers Summary.
Sept. 1995	IPCC Plenary adopts SAR.
Oct. 1995	SAR printed and distributed.

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Schedule for the Work of Working Group III

Revised July 30, 1993

Sept. 1993 to Aug. 1994	Workshops are held and lead authors prepare first drafts of Second Assessment Report (SAR) chapters.
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List of Workshops

WORKING GROUP III WORKSHOPS

January 17-20, 1994
Japan

Policy Instruments and their Implications

Japan has expressed interest in organizing a workshop for WG III January 17 - 20, 1994. They will be asked to consider a workshop on policy instruments and their implications.

Late March/Early April 1994
Switzerland

Decision-making framework

Mid-April, 1994
Brazil

Greenhouse Gas Emissions Scenarios

A workshop on the review of current emissions scenarios will be held in Fortaleza, Brazil in April, 1994.

July, 1994
Kenya

Equity and Social Considerations: What is Science? What are Values?

This workshop will be held in Mombassa, Kenya in July 1994. The writing team addressing equity and social issues will be asked to provide suggestions for the agenda that will help them with their work.

October 1994

Sustainable Development, Cost-Benefit Analysis and Decision Making Related to Global Warming

Saudi Arabia has indicated that it might be interested in hosting a workshop for WG III. It will be asked to host this workshop in October, 1994.

Summer 1994

Top-Down and Bottom-Up Modelling: What Can We Learn from Each Approach?

IPCC WORKSHOPS OF INTEREST TO WORKING GROUP III

The IPCC has been specifically requested to provide advice to the first Conference of the Parties (COP) to the Framework Convention on Climate Change (FCCC) on Article 2 of the Convention. This advice is expected to be based on the results of two workshops.

Mid-April, 1994
Brazil

First Workshop on Article 2 of the FCCC

The first workshop will deal with emissions scenarios, stabilization of atmospheric concentrations, regional climate change scenarios, and implications for impact assessments. WG I is organizing this workshop which will be held in Fortaleza, Brazil in mid-April, 1994.

**August, 1994
Zimbabwe**

Workshop on Desertification

WG II is organizing a workshop on desertification to be held in Harare, Zimbabwe in August, 1994. It is expected that adaptation, mitigation, and socio-economic impacts will be important issues for this workshop.

January, 1995

Second Workshop on Article 2 of the FCCC

The second workshop will be held in January, 1995.

NON-IPCC WORKSHOPS OF POTENTIAL INTEREST TO WG III

**October 13-15, 1993
Laxenburg, Austria**

**IIASA workshop on the interrelationships between
adaptation and mitigation measures.**

Dr. Haites will attend on behalf of WG III.

**October 20-22, 1993
Cambridge, Massachusetts**

MIT Global Change Forum V

The forum will review progress in integrating climate and energy/economic models and discuss next steps in integrated assessment.

Dr. Haites will participate on behalf of WG III.

**November 8-10, 1993
Lisbon, Portugal**

**IPIECA Seminar on Socio-Economic Aspects of Global
Climate Change.**

**December 6-10, 1993
Perth, Australia**

**Modelling Change in Environment and Socio-economic
Systems.**

Sponsored by International Environmetrics Society, International Society for Ecological Modelling et al., University of Western Australia

Contact: Tony Jakeman, 61 6 249 4742

**December 13-15, 1993
Maastricht, Netherlands**

Non-CO₂ Greenhouse Gases: Why and How to Control?

International Symposium organized by the Society for Clean Air in the Netherlands. The European Symposium on Environmental Protection.

Contact: Vereniging LUCHT, 31 15 696884

**June 1 -3, 1994
Groningen, Netherlands**

International Conference on Joint Implementation

Organized by the Foundation International Development Economics in cooperation with the Netherlands' Ministry of Housing, Physical Planning, and the Environment.

Issues and Parameters Common to Multiple Writing Teams

The IPCC has adopted sustainable development as the criterion for decisions related to climate change. Can we specify an operational definition of sustainable development in this context? Is stabilization of atmospheric concentrations at current levels a reasonable definition?

Can the benefits of avoiding climate change be estimated in a manner consistent with the definition of sustainable development and with sufficient accuracy to apply benefit-cost analysis?

What is an appropriate (range for the) social discount rate applied to climate change?

What is an appropriate decision making framework for dealing with climate change given the scientific uncertainties, the long time horizon, and the potential for irreversible environmental changes?

What approaches can be used to establish guidelines for inter regional and intergenerational equity and resource transfers from developed to developing countries?

Can we distinguish the costs of achieving a greenhouse gas emissions target from the cost of the policies used to achieve the target?

Can limits be defined for the contributions of different technologies, such as energy-efficiency, nuclear, and biomass, to limiting greenhouse gas emissions?

Is it useful to establish an optimal trajectory of greenhouse gas emissions targets?

What are the costs of unilateral action to limit greenhouse gas emissions? Can action by a few countries reduce costs for those countries? Can such a group be structured to make participation by non-participants attractive to everyone?

Do emissions scenarios depend more on the model or the key input assumptions?

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Travel Arrangements

Please make your own flight arrangements.

The lead authors meeting will be held at the Sheraton Walker Hill Hotel in the eastern part of Seoul. A special rate of U.S. \$143 per night, including VAT and service charge has been negotiated. The hotel address, telephone and fax numbers are as follows:

Sheraton Walker Hill Hotel and Towers
San 21, Kwangjang-Dong, Sungdong-Ku
Korea 133-210
Tel: 82 2 453 0121/0131
Fax: 82 2 452 6867

**PLEASE MAKE YOUR HOTEL RESERVATIONS THROUGH DR. JOO HEON PARK
AT THE KOREA ENERGY ECONOMICS INSTITUTE; TEL +82 343 20 2271, FAX +82
343 21 0688.**

The hotel is approximately 90 minutes from Kimpo International Airport by bus. A KAL limousine bus runs from the airport to the hotel with departures every 30 minutes. The bus fare is 3,500 Won.

Travel Documents

YOU MAY NEED A VISA. Please check with your travel agent or Korean embassy/consulate/travel office to determine whether you need a visa.

If you need a visa, you will need to provide three Korean references. You can use the following references:

Dr. Jeong-Shik Shin
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and Coordination Division
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665-1, Naeson-Dong, Euiwang City
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Dr. Jin-Gyu Oh
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Korea Energy Economics Institute
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Kyungki-do, Korea 437-082
Tel: 0343 20 2270

Dr. Joo-Heon Park
Energy and Environment Division
Korea Energy Economics Institute
665-1, Naeson-Dong, Euiwang City
Kyungki-do, Korea 437-082
Tel: 0343 20 2271

**C. WORKPLAN OF THE IPCC
REORGANIZED WORKING GROUP III**

Explanatory Notes

Scope of Work

The efforts of the newly reconstituted Working Group III of IPCC will be carried out in the manner described in this work plan. Attached, and forming part of the work plan are the outline of the themes to be considered in the Working Group III Second Assessment Report (SAR) (Annex D) and the time-line for completion of various phases of the work (Annex G).

The Working Group will, in accordance with its Terms of Reference (see Annex C), prepare a comprehensive technical assessment of the socio-economics of mitigation of climate change, the impacts of climate change and adaptation to climate change over both the short and long term and at the regional and global levels. This contrasts with the work of Working Group II, which will be assessing the economic impacts on particular economic sectors at a more local level. Nevertheless, considerable collaboration between the two working groups will be necessary.

As reflected in United Nations General Assembly document A/AC.237/30 the chair of the Intergovernmental Negotiating Committee (INC) for the Framework Convention on Climate Change has requested that IPCC prepare, in time for the first meeting of the Conference of the Parties to the Convention (COP), "an evaluation of current scenarios of greenhouse gas¹ emissions and removals by sinks". The proposed time line addresses this request and assumes that the first meeting of the COP will take place in the spring of 1995. If this turns out not to be the case, the timing of activities shown that relate to the evaluation of scenarios would be adjusted accordingly. This element of the work is expected to build heavily on the work of the 1992 IPCC Update, which contained six greenhouse gas emissions scenarios. It is suggested that this work be carried out by examining the major assumptions made in developing the original scenarios and, based on whatever new information is available, assessing the validity and appropriateness of those assumptions and making recommendations on the need for updated or new scenarios. If it is agreed that new scenarios are needed, actions will have to be taken to develop them for the Second Assessment Report. The work on responding to the INC request will be closely co-ordinated with that on the same issue for the SAR by involving the same group of contributors. The IPCC Bureau is seeking clarification of the other elements of the INC's request, which raise cross-cutting issues which Working Group III may need to consider.

In evaluating scenarios and in developing its scientific and technical assessment, the Working Group proposes to undertake a number of specific activities, which are described in this work plan.

Principal Considerations

The work of the Working Group will be carried out with the following considerations in mind:

- a) It will place the socio-economic perspectives of climate change in the context of sustainable development. In particular, and in accordance with the Framework Convention on Climate Change, the work of the Working Group will be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation and comprise all economic sectors.
- b) Institution and endogenous capacity building in developing countries will be integrated into the work programme.
- c) The work of the Working Group will not stand in isolation from other IPCC

¹Throughout this document, the term "greenhouse gas" is as defined in Article 1 of the Framework Convention on Climate Change

activities. Consultation and co-ordination with the activities of the other Working Groups will be carried out to the greatest extent possible.

- d) The work will, to the greatest extent possible, build on existing work, recognizing that the IPCC role is one of assessing existing knowledge for the Second Assessment Report.
- e) The activities of the Working Group will take into account the special situations of developing countries and economies in transition and will be carried out at a pace and be of a type that allows for the full involvement of these countries.
- f) The work will be carried out in as cost-efficient a manner as possible, bearing in mind the limited resource capacity of IPCC and all member countries. This implies close co-operation with other bodies working in the same fields in order to avoid duplication of effort.

**Activities of
the Working
Group**

The Working Group will prepare a report comprising its contribution to the IPCC Second Assessment Report and containing a technical assessment of the state of knowledge of the socio-economics of climate change mitigation, adaptation and impacts, taking into account the factors described in part (a) of the Terms of Reference of the Working Group. It is proposed that the structure of this report follow the proposed outline of the themes shown in Annex D.

The Working Group will also prepare a report, in time for the first meeting of the Conference of the Parties to the Convention, on the validity, appropriateness and utility of existing net greenhouse gas emissions scenarios based on the factors described in part (b) of the Terms of Reference of the Working Group. An update of this report, including any new scenarios that it is agreed should be developed, will be included in the Group's contribution to the IPCC SAR.

The preparation of both reports would be carried out as follows, using the dates indicated in the time line in accordance with the procedures described in the IPCC proposal for procedures for preparation, review and adoption of IPCC reports:

- The Bureau of the Working Group will ask governments and participating organizations to identify experts in their countries who could be involved as part of teams of lead authors, contributors, and expert reviewers for each report. Governments will also be asked to identify IPCC contacts for the purpose of co-ordinating later review by their governments.
- The Bureau of the Working Group will ask governments to suggest themes, dates and locations for IPCC workshops that could be held to review the scenarios and the scientific and technical work that is being assessed, bearing in mind the principal considerations noted above and the IPCC workshop policy. For reasons of economy and to avoid overlap and duplication, the Bureau will co-ordinate with other IPCC Working Groups and international organizations in conducting these workshops.
- Based on the suggestions of governments and participating organizations, the Bureau will meet with the Chair of IPCC and possibly with some of the experts identified, to decide on the detailed contents of each section of the reports, assign teams of lead authors for each section, and decide on which workshops should be held. The Bureau will also decide, from the perspective of Working Group III, whether IPCC co-sponsorship should be extended to other workshops, seminars or meetings.
- Lead authors will undertake preparation of the first drafts of each section and submit them to the Co-chairs, bearing in mind the tasks and responsibilities identified for contributors and themselves.

- The first drafts will be circulated for peer review to the specialists. Referenced material will be made available by the Co-chairs, who will collect the comments of the reviewers and make them available to the lead authors. Lead authors will then revise the drafts and if time permits in the schedule indicated in the time line, Co-chairs will circulate the revised drafts again for review.
- The revised drafts will be sent to governments and participating organizations for review.
- The summary for policy makers will be approved at a meeting of the Working Group in Plenary session and adopted by the Panel.

TERMS OF REFERENCE OF IPCC WORKING GROUP III

Working Group III should deal with cross-cutting economic and other issues related to climate change. Two issues have been identified below at this stage. The IPCC may add other issues at subsequent plenary sessions. The Working Group shall establish its work plan for tasks (a) and (b) below, which shall be available to the IPCC for subsequent review as its work proceeds.

- (a) Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, inter alia, consider the following topics: top-down and bottom up economic modelling while taking into account assumptions, variables and applicability to and in different national economic circumstances; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments provided, however, that none of these tasks shall involve the Working Group in making policy judgements.
- (b) The Working Group should consider and develop as necessary a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections, and taking account of gaps and uncertainties in available knowledge, especially concerning the evolution of socio-economic development and technology; where possible, policy assumptions should reflect their economic and social consequences. The scenarios are intended to assist Working Groups I and II in their assessment of a range of future changes of atmospheric composition, resulting climate changes, and their impacts.

This work should be carried out in consultation with Working Groups I and II.

A peer review process should be incorporated in the preparation of the reports of the Working Group.

OUTLINE OF THE THEMES TO BE CONSIDERED IN THE WORKING GROUP III SECOND ASSESSMENT REPORT

PREFACE

The preface will outline the mandate and terms of reference of the working group, describe how it went about producing the report, what the intended audience of the report is and the purposes for which the report should be used. The preface will note that none of the tasks shall involve the Working Group making policy judgements. Each chapter will also place the socio-economic perspectives of climate change in the context of sustainable development. The working group should analyze the issues as broadly as possible recognizing the Rio Declaration on Environment and Development, Agenda 21 and in particular the Framework Convention on Climate Change, as adopted.

EXECUTIVE SUMMARY

SUMMARY FOR POLICY-MAKERS

THE SECOND ASSESSMENT REPORT

The SAR consists of three parts. The first part addresses the scope of the assessment, and the remaining two parts address the mandate of the Working Group.

PART I: SCOPE OF THE ASSESSMENT

This assessment will include, inter alia, the socio-economic perspectives of climate change, the nature of the interactions between economic activity and climate change, and emissions scenarios. The assessment will address the global nature of the problem, taking into account particularly the circumstances of countries vulnerable to the impacts of climate change and to the impacts of response measures. In addition, it will cover a scientific evaluation of the appropriateness of the methodologies used for the analysis, including the socio-economic assumptions underlying existing modelling frameworks, its relations to observable data such as national accounts figures (GDP). To fulfil the scope of the analysis, existing supplementary indicators will be assessed.

PART II: THE SOCIO-ECONOMICS OF IMPACTS, ADAPTATION AND MITIGATION OF CLIMATE CHANGE

The mandate of the Working Group states that it should undertake "Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, inter alia, consider the following topics: top-down and bottom up economic modelling...; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments...". For each theme in this part, a key question to be answered that addresses this section of the mandate has been identified.

CHAPTER 1: SOCIO-ECONOMIC FRAMEWORK FOR DECISION-MAKING

Key Question: How do we take socio-economic factors into account when making decisions about the climate change issue? The issues addressed under this theme will include, inter alia:

Socio-economics of climate change in relation to the need for sustainable development

Decision-making under uncertainty

The socio-economic factors to be considered when making decisions in the short and long term.

Risk assessment including, inter alia, discussion of the following questions:

What methods can be used to assess risk and what levels of confidence can be attached to such methods?
What are the perceptions of and responses to risk?
What are possible response measures?
What are the risks of inaction and of undertaking "no-cost" or cost effective "low-cost" response measures and of taking more far reaching response measures? (This section should take into account sequential decision-making, portfolio analysis, benefits and costs of taking action early versus late, and the long-term implications of short-term decisions).

Equity considerations including, inter alia:

Varying contributions between regions for past emissions, the "free rider" problem, efficiency and consumption patterns, inter-regional and inter-generational equity and the question of the time lags between the incurring of costs, the accruing of benefits and/or disbenefits.

Methods and applications of cost-benefit analysis including, inter alia:

Concepts such as opportunity costs, trade-offs, marginal costs and marginal benefits, limitations of cost-benefit analysis and consideration of alternative methodologies, and the value and importance of non-market factors such as biodiversity, long-term discounting, public perceptions, social well-being, thresholds and irreversibilities.

The value of information including, inter alia, discussion of the following:

Significant efforts are being undertaken every year on global climate research in the area of natural sciences. Where are the highest potential payoffs for likely future decisions? What are the most critical uncertainties, including scientific uncertainties? What kinds of research can reduce them and reinforce society's ability to confront uncertainty? What is the value of this scientific research in terms of its ability to describe the linkages between the natural sciences and socio-economics? What are the predictable trends of scientific and technical progress in efficiency of use of different energy types with respect to carbon intensity and in the adaptation of species to new climatic situations?

Sociological considerations

CHAPTER 2: ASSESSING THE BENEFITS OF RESPONSES TO CLIMATE CHANGE

Key Question: What methods exist for assessing the economic and social benefits of action and inaction? The issues addressed under this theme will include, inter alia:

Methods for estimating benefits

The status-quo option. What would be the socio-economic impacts in the absence of any action to deal with the problem of increasing concentrations in the atmosphere of greenhouse gases and aerosols? How would the benefits vary with different degrees and timing of actions to limit climate change?

Methods based on market impacts - for example, adaptation through trade, market agents, migration of population and economic activity.

Methods based on non-market impacts such as ecological and social impacts.

Major issues in estimating benefits

An assessment of the state of knowledge related to issues involved in estimating benefits, including, inter alia, distinguishing between short-term and long-term impacts; the relationship of impacts to the degree, timing and predictability of climate change; techniques for valuing impacts on ecosystems; hard-to-define values such as aesthetics, impacts on land use, impacts on biological diversity and other environmental problems, social well-being; and modelling limits dealing with thresholds, irreversibilities and time horizons.

Methods for estimating the costs of human adaptation

CHAPTER 3: EVALUATING THE COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS BY SOURCES AND REMOVAL BY SINKS

Key question: What are economic, social and environmental contributions to understanding, both conceptually and empirically, the costs of mitigation of greenhouse gas emissions? The issues addressed under this theme will include, inter alia:

Variables for measuring costs

A discussion of costs from a long-term perspective, including, inter alia, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.

Assumptions in empirical analysis including, inter alia:

- Modelling assumptions including uncertainties and ranges
- Technological change
- Macro-economic and demographic assumptions such as productivity growth, population and labour force change and structural change in economies
- Consumption patterns
- Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities and exchange rates
- Land use

Policy instruments, and their potential effects, for domestic and regional use including, inter alia:

- Economic instruments such as taxes, subsidies, tradeable permits, tradeable absorption obligations, user charges and deposit-refund schemes
- Regulatory instruments including technology-based and performance-based
- Other instruments such as land use programmes and public awareness and education programmes

Modelling Methods

A description of various types of models (eg. "top down" and "bottom up") according to purpose, and a discussion of their relative strengths and weaknesses, including, inter alia, a discussion of data limitations and limitations of model applications, the reasons for differences in the predictions made by them and ways to evaluate those results, and the integration of modelling techniques (eg. bottom up studies of new technologies). The appropriateness of the modelling methods should be discussed in relation to the problems of developing countries and should reflect the concerns and special conditions of developing countries. The models should include as many different policy instruments as possible. Possible other issues include dynamic versus static models, econometric

versus parametric models, perfect versus limited foresight in models, the treatment of international trade, model time horizons and how various modelling techniques could be integrated. Different policy options will be used to derive model outputs.

Model Comparisons

A comparison of results including, inter alia, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries and a survey of the degree of dependency of countries on the production, exportation and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

Major issues of cost estimation

Potential topics include, inter alia, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.

Topics for future work

A discussion of the types of future research needed such as the integration of bottom up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

CHAPTER 4: GENERIC ASSESSMENT OF RESPONSE OPTIONS

Key question: What methods exist for assessing the net costs and effectiveness of different response options in a comprehensive manner?

The discussion of cost evaluation in each of these sections should incorporate a discussion of net costs and should include complementary socio-economic effects, both negative and positive, on such elements as GDP, employment levels, the balance of trade, economic structure, and the environment. The issues addressed under this theme will include, inter alia:

Adaptation options

A discussion of different options for developed countries, developing countries and those with special circumstances (e.g. low lying, arid, and countries in transition).

Mitigation options

A discussion of mitigation measures which should reflect, for example, the concept of comprehensiveness (all greenhouse gases and sinks and sectors), including, inter alia, reducing emissions by correcting market and government policy shortcomings, eliminating subsidies and barriers, dissemination of information and technology co-operation, and introducing economic instruments.

Methods for assessing the effectiveness of options including, inter alia, the use of models and the extent to which models incorporate the full range of options and conditions

Comparison within and between mitigation and adaptation response options

The comparison should include, inter alia, their cost effectiveness, their influence on innovation and promoting environmentally sound technologies, their influence on other environmental matters, their ease of administration monitoring and enforcement, their capacities to cope with uncertainties, their data requirements and equity and sustainable development considerations.

Technological change

A discussion of the factors determining technological change as a driving force for, as well as a way to control net greenhouse gas emissions (e.g. renewable energy, low energy systems, carbon sequestration, etc.), taking into account the penetration, diffusion and transfer of technology and the different dynamics in developed and developing countries; and which of these factors can be influenced and how.

Internationally-coordinated instruments

A discussion of mechanisms such as "joint implementation", carbon leakages (shifts of carbon-intensive activities) linked to demographics, consumption patterns and economic growth of industrialized and developing countries, assistance and trade aspects, and the possibilities and difficulties of internationally co-ordinated instruments.

PART III: EMISSIONS SCENARIOS

CHAPTER 5: CONSIDERATIONS OF CONSISTENT SCENARIOS

The mandate of the Working Group states that it "should consider...a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections." With this in mind, the key question to be answered is "Which issues and uncertainties about key variables may critically affect future net greenhouse gas emissions and aerosol concentrations?"--The issues addressed under this theme will include, inter alia:

Types of models for scenario development and their application

The assumptions made in developing existing scenarios

A discussion of the key assumptions concerning, inter alia, economic growth, demographics, consumption patterns, technological change, energy prices and supply, international trade flows, distributional issues, social change, sustainable development, land use, and non-greenhouse gas environmental constraints such as acid rain.

The relative importance and sensitivity of different variables in determining future emissions and sinks

The relationships among key variables

The sensitivity of these variables, most notably to government actions

The relationship of scenarios to the emissions inventory methodology developed by Working Group I

- A number of country studies are being completed and could make a useful contribution to scenario analysis

The degree of uncertainty including, inter alia, a discussion of the following questions:

- What are the gaps and uncertainties in available knowledge about these factors and their influences on emissions?
- What does the extent of this uncertainty tell us about the validity of current scenarios? How do existing IPCC scenarios compare with other existing scenarios? Are new scenarios required?
- What are likely to be the impacts of this uncertainty on short and long-term future emission scenarios?

Model structures for analysis of scenarios including, inter alia, a discussion of the following questions:

- How useful are current models in terms of their regional detail, solution algorithms and data?
- What are the characteristics of current models?
- The sensitivity and flexibility of models to technical and structural assumptions

The appropriate uses, capabilities, and limitations of emissions scenarios in scientific assessment and policy-making

An assessment of the need for future work on scenarios to serve the needs of climate modelling, planning of response measures, and provision of information to the Conference of Parties to the Framework Convention on Climate Change

**APPLICABILITY OF COST-BENEFIT ANALYSIS
TO CLIMATE CHANGE**

Prepared for WORKING GROUP III
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1. Introduction

In public policy-making, a comparison between the perceived costs and the perceived benefits of an action is routinely made by decision-makers. However, this choice is frequently made on intuitive and qualitative grounds. Cost benefit analysis (CBA) provides an analytical framework that seeks to compare the consequences of alternative policy actions on a quantitative rather than qualitative basis. Indeed, the approach forces quantitative thinking, for its very essence is that costs and benefits must be expressed in a common monetary unit that provides the basis for the tradeoffs. The basic principles are well understood and straight forward: for an action to be justified, the costs of the action should be less than the benefits derived therefrom¹. If there are several alternatives, then one ought to pick that option whose benefits most exceed the costs².

The objective of this Chapter is to examine how and under what circumstances can CBA make a contribution to the resolution of the central questions now facing decision-makers about global climate change: (1) by *how much* should emissions of greenhouse gases (GHGs) be reduced? (2) *when* should emissions be reduced? (3) *how* should emissions be reduced? and (4) *who* should reduce emissions? CBA can at least theoretically and conceptually answer the first three questions. The fourth question is one of equity, and not amenable to resolution by CBA even in simple, traditional applications not complicated by the complexities of the climate change problem³.

Section 2 defines more carefully what is meant by CBA: in fact the term has come to encompass a wide variety of specific techniques. We also review the basic concepts. In section 3 we examine the unique features of global warming and climate change as they pertain to decision-making. Section 4 presents a discussion of the application of CBA to the climate change problem in light of these unique features. In section 5 we discuss the key issues: risk uncertainty, irreversibility, valuation, discounting, equity, and multiple criteria.

¹ Indeed, that cost-benefit analysis is appropriate to the analysis of policy options to address global climate change is not universally accepted. A major report recently issued by the US Office of Technology Assessment (OTA, 1993) contains an extensive discussion of how adaptation strategies should be chosen, yet manages to avoid all mention of cost-benefit analysis *per se*. It talks about how one might minimize vulnerability to climate change and about insurance strategies, but avoids the central question of how one might determine the amount of insurance one wishes to buy. Similarly, priorities may be set on non-economic grounds, and CBA could be used in a secondary role (see e.g. Turner, 1991).

² Although this needs a little bit of modification in the presence of capital constraints, which may limit selection of the "best" single project.

³ However, as we shall see later, extensions of CBA can help in identifying the *trade-offs* between economic efficiency and equity.

2. Cost-benefit analysis

Cost-benefit analysis (CBA) is a generic term that subsumes a wide body of specific techniques. Developed originally as a means to evaluate projects, the original techniques have been extended to cover applications of increasing complexity.

Traditional project level CBA

CBA evolved as a technique to evaluate and compare project alternatives. In the early years of its application, there was little concern with externalities, and the analysis took into account just the direct costs of projects, and the direct benefits. Developed in the west, market prices provided appropriate guidance on how to evaluate benefits. But even as the World Bank began to apply the technique to non-market economies, or where prices were subject to significant distortions, shadow pricing techniques provided simple corrections.⁴

One of the central concepts in CBA is that of discounting, which addresses the fact that costs and benefits may not occur at the same point in time. Thus, while costly actions to avoid future global warming must be taken now, the benefits of such actions may arise very far in the future. Discounting enables one to take into account the time value of money. In the case of evaluating simple investment alternatives over shorter time horizons (e.g., < 15 years), the use of the opportunity cost of capital as the discount rate to be applied to both costs and benefits, is well established and uncontroversial. However, in the case of complex public policy applications, particularly those whose time horizons are very great, and involving environmental impacts or the depletion of natural resources — essential characteristics of the global climate change issue — there is sharp disagreement as to what discount rate is appropriate. This issue is dealt with in Section 5.

Cost-effectiveness analysis

As CBA began to be applied to much broader contexts, and particularly to the comparison of alternative *portfolios* of projects and to broad policy choices, the increasing complexity made it desirable to keep the level of benefits constant, and to analyze the problem simply in terms of finding the most effective, or "least-cost" option to meet the desired level of benefits. This has the additional advantage that benefits in some cases do not need to be explicitly valued. For example, in power sector planning, models are applied to identify the capacity expansion plan whose present value of system costs are minimized, given some exogenously specified time path of electricity demand, and some exogenously specified level of reliability. As we shall see below, this is the variant of CBA that has seen the most widespread application to the climate change problem, in which one seeks to identify the least-cost option to achieve given levels of GHG emission reductions, without any explicit attempt to specify what the *benefits* of that level of emission reduction may be.

The Framework Convention on Climate Change emphasizes that "policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost." Being a global matter, most of the actions that will be taken to mitigate climate change will be equally efficient independent of where in the world the action takes place. Strictly speaking, therefore, cost effective measures are those that minimize total world cost, given a target for the world as a whole.

⁴ For example, if an oil-importing country kept the domestic price of oil at artificially low levels, CBA requires the use of the border price, not the domestic price, as a basis for costing oil inputs.

The importance of CBA in relation to cost effective mitigation of climate change depends partly on the kind of measure that is considered. Analysis of general measures, such as carbon taxes) is straight forward, assuming that market behavior leads to cost minimization based on the prices of the taxed goods and services. Cost effectiveness is then a question of a proper tax. A global marketable permit system would result in permit prices equivalent to the proper tax — if countries could agree on the target level and how to share the initial distribution of permits. Responses based on the efficient functioning of markets would similarly lead to cost minimization. For a closer examination, see Hoel (1992).

For the evaluation of investments in GHG emissions abatement, CBA will play a more central role. Cost effective measures should be evaluated on the basis of global models in which economic interdependencies between world regions are taken care of. However, such models have to be quite aggregate, and will generally not allow the evaluation of measures for which a rather detailed description of national economies is required. Measures that aim at sectoral substitution within energy intensive industries may be such an example. To evaluate such measures, national macro-economic models might be applied. These will have to take certain conditions on the world market as given — conditions that might change if many countries initiated climate measures.

Many of the potential climate change mitigation measure require a rather detailed technical description to be evaluated. In these cases CBA would normally assume all the prices to be fixed at observed market prices. If introduced on a large scale, however, these kinds of measures might affect market prices at the world level. Thus, a fully consistent evaluation of cost effective measures may require analysis at several levels of aggregation.

In order to evaluate cost effectiveness it is crucial to clarify in what terms the target is set, because there are several options in the global climate change context. Most of the recent analyses of the cost of mitigation have focused on targets of future emission levels⁵, such as stabilization of the emission of certain greenhouse gases by a given year. However, it might be more relevant to express the targets in terms of concentrations of atmospheric greenhouse gases.

To change the target for climate policy from emissions to atmospheric concentrations indicates a radically different cost effectiveness strategy. A stabilization of CO₂ emissions at present levels is not sufficient to stabilize the atmospheric concentrations. Richels and Edmonds (1993) have compared the costs of reaching the same concentration level by year 2100 from alternative strategies. They show that the same concentration level can be met at a considerably lower cost than the cost of stabilizing emissions immediately. The reason being that the economic shock following a sudden stabilization of emissions is avoided, future advanced technologies could be utilized to a larger extent, and sizable abatement costs are postponed.

A third possible target, also affecting the cost effectiveness of alternative measures, could refer to the physical consequences of climate change. Apart from the fact that predictions of these consequences are far more difficult to make than predictions of emissions and atmospheric concentrations of greenhouse gases, the effects of regional differences would have to be included if targets were set on the consequences. For instance, whether global warming contributes to sea level rise or to an increase in the frequency of rain storms will be of quite different importance to people in Nepal and Netherlands. In this context, an additional problem

⁵ The degree of emission abatement is reported in such studies in two rather different ways. The first is as reductions from some baseline, defined as the trajectory of GHG emissions for some postulated business-as-usual scenario. The second is in terms of reductions from some reference year (e.g. "reduce greenhouse emissions to 80% of their 1990 levels by 2010")

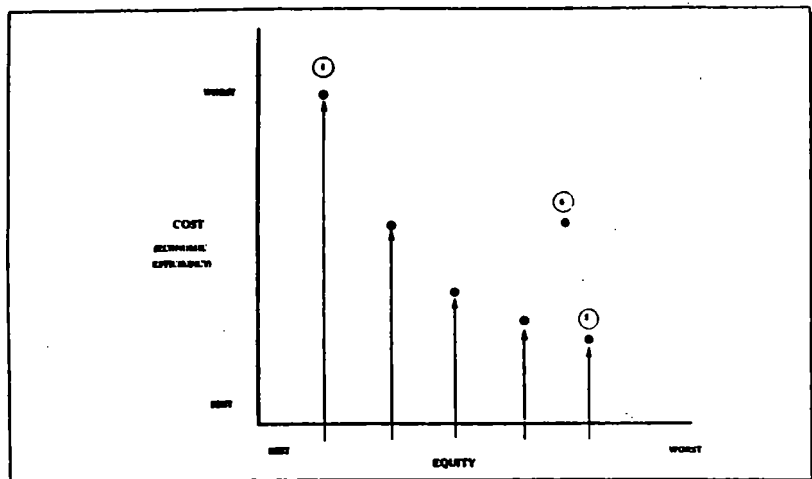


Figure 2.1: Multi-criteria analysis

arises as to how to assess benefits from abatement of different consequences for different countries.

Multi-criteria analysis

The most basic requirement for the application of CBA is that both costs and benefits can be given economic value. This is typically a two step process: first the costs and benefits must be quantified in terms of the physical measures that apply; and then those physical impacts must be valued in economic terms.

Some applications of valuation techniques are likely to be controversial. Putting a value on human health and illness has been a major problem in the practical application of cost-benefit analysis in the past, even in those situations where one can agree upon the levels of increased morbidity and mortality that might be caused by some policy or project. Efforts to place economic value on the loss of biodiversity have been equally difficult. Recognizing this problem has led to the development of so-called multicriteria analysis (MCA) techniques, which are expressly designed to deal with multiple objectives – of which economic efficiency is indeed only one of several that may be employed.

Even if one can place economic value on certain impacts – such as human life – not everyone agrees that it is *appropriate*. Indeed, cost-benefit analysis presupposes that costs and benefits are those perceived by humans – an endangered species might view the trade-off between threatened habitat and GHG emissions in an entirely different way, and use a different numeraire than money⁶. Such views give further support for MCA-based approaches to

⁶ A recent survey of economists and scientists knowledgeable about the climate change problem elicited typical views at the extreme of this spectrum. One respondent argued "the existence value of species is irrelevant – I don't care about ants except for drugs", while another cautioned that "loss of genetic potential might lower the income of the tropical regions substantially". In Section 5 we address the different types of value – use, option, existence – in more detail. (W. Nordhaus, Expert Opinion on Climatic Change, *American Scientist*, 82, 45-51, 1994).

decision-making. Similarly, there are concerns that monetized values themselves may be inaccurately estimated, and in any case such values might not reflect welfare.

As noted earlier, conventional CBA cannot provide answers about the optimum level of equity in the same way that it provides answers about the optimum level of economic efficiency. But MCA can identify the *trade-offs* between equity objectives and economic efficiency, as suggested by Figure 2.1. Thus, the best equity result (indicated by option 1, say an equal per capita sharing of the burden of GHG emission reduction) may have the highest cost; while the worst equity result (indicated by option 5, say based on the present distribution of GHG emissions), may have the lowest economic cost⁷. Nevertheless, even MCA requires a quantification or at least an ordinal ranking of the non economic efficiency criteria, as suggested in the figure. However, even such a non-cardinal ranking may prove problematic when a global issue like climate change requires comparisons across countries and cultures.⁸

Decision analysis

While MCA addresses certain shortcomings of conventional CBA (like valuation problems), it does not necessarily deal more effectively with uncertainty. Thus has developed a further extension of CBA that goes under the general term decision analysis. Here the focus is expressly on how one makes decisions under conditions of uncertainty. These techniques find application in a wide variety of situations, from decision-making in the high risk field of wildcat oil drilling to analysis of financial options. As we shall see below, these techniques provide a rational approach to deal with irreversibility, one of the more important characteristics of the climate change problem.

Basic concepts

An economically efficient policy for emissions reduction is one that maximizes the net benefits, i.e. maximizes the benefits of reduced global warming less the associated costs of emissions reductions⁹. Economic theory provides that emission reduction efforts should be pursued up to the level where the marginal environmental benefits of an additional unit of reduced warming is equal to the marginal cost of emissions reduction. Figure 2.2 illustrates the concepts of total and marginal costs in simplified form – the marginal costs at any level of emission reduction is equal to the slope of the total cost curve at the same level.

The shape of the total cost and benefit curves reflects the idea of diminishing returns. Each additional unit of emissions reduction will have a higher unit cost: the first 10% reduction can be done cheaply, but the next 10% will cost considerably more, and so on.¹⁰ Thus the

⁷ But see below for a discussion of the difficulties of making cross-country comparisons of costs.

⁸ There may also be some outcomes that are inefficient, i.e. those that lie inside the frontier of efficient points shown on Figure 2.1. Such an inefficient point is represented by option 6. This is discussed further in the presentation of multi-criteria analysis, below.

⁹ It should be noted that the algebra of cost-benefit analysis can be expressed in many different ways: the cost-benefit ratio, net present value, or the internal rate of return are all different ways of doing the arithmetic. However, particularly in situations involving portfolios of potential actions, and where shortages of capital may constrain the choice, great care must be paid to rigorous application of principles, else different methods can yield different decisions. Maximizing net present value subject to applicable resource constraints is the most useful approach for climate change analysis.

¹⁰ Perhaps the simplest and most intuitive example as to why the marginal cost of emissions reduction increases with increasing levels of reduction is the removal of pollutants from wastewater. The first 60% can be easily removed by a settling basin, that require just a structure. Large particles

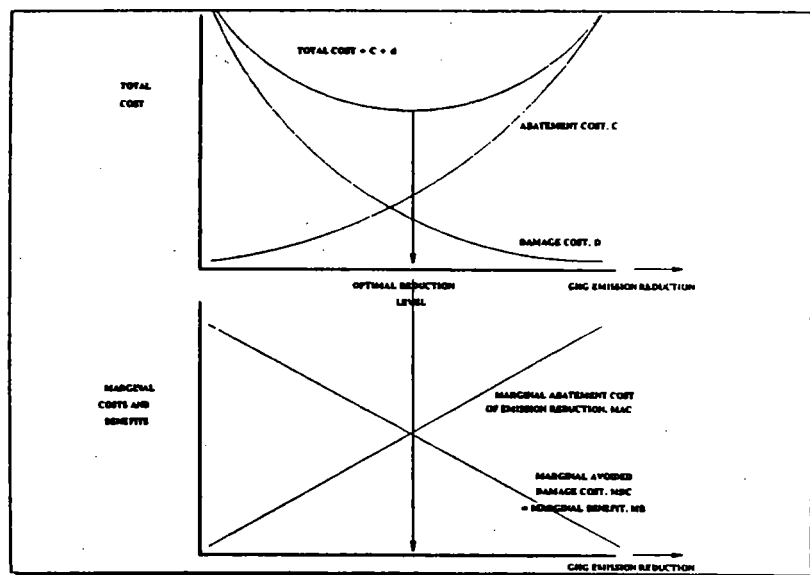


Figure 2.2: Total and marginal costs and emissions reductions.

abatement cost curve is upward sloping (with increasing slope) as shown on Figure 2.2A. Similarly, the marginal benefit (or avoided cost of GHG damages) falls as emission levels are reduced. The consequences of the foregoing is that the total cost (TC) has a minimum at the point where the slope of the abatement cost curve equals the negative slope of the damage cost curve (or avoided costs).

The foregoing analysis ignores many complications. For example, the emission of a unit of CO_2 may give rise to a varying stream of environmental costs which must be discounted to yield a present value aggregate. The environmental damage function may be discontinuous and non-convex. Abatement costs may change over time, depending on when the technologies are applied – because of technological progress. Similarly, abatement costs may exhibit economies of scale (e.g. mass production of solar photovoltaic cells), resulting in a marginal cost curve that actually declines beyond a certain point. Finally, the abatement costs are net costs, to the extent that certain technologies (e.g. renewables) may produce other (non-climate related) benefits and costs – the so-called joint products complication.

simply settle by gravity. The next 30%, to reach, say 90% removal, requires biological treatment: this requires not just a physical structure, but pumps to aerate the water to promote aerobic bacteria. The next 5-6% requires chemical treatment, with high operating costs of chemical agents. 100% removal, theoretically possible, would require complete distillation, which is extremely expensive.

3. Unique features of global warming

There are several important characteristics that define the conventional context in which CBA is applied. First is that costs and benefits arise within a time span typically no more than 15-25 years, corresponding roughly to the physical life of most projects over which benefits are derived. Second is that the elements of uncertainty are relatively tractable, and can often be characterized by probability distributions.

Most of these characteristics are very different in the context of global warming. The relevant time spans extend to a century or more. The uncertainties are extremely large, and few elements of uncertainty are amenable to characterization as probability distributions.

Figure 3.1 shows the chain of causality. It begins with emissions of greenhouse gases. While the most important of these is CO_2 , it should be noted that there are many other gases that contribute to the global warming phenomenon, including methane, and CFCs. While estimates of CO_2 emissions from fossil fuel combustion are fairly straight forward, emissions from other sources are subject to much higher uncertainty.

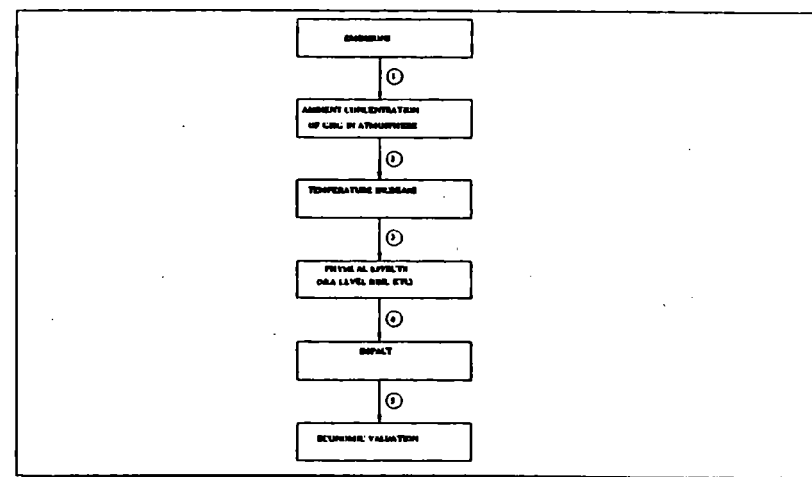


Figure 3.1: The chain of causality

The first link (1) is between emissions and the resultant ambient concentration of CO_2 in the atmosphere. Unlike other pollutants that are subject to complex chemical transformations in the atmosphere,¹¹ the calculation of the ambient concentration increase that follows from a given increment of emissions of CO_2 is relatively simple. However, because of the role of natural sources and sinks (particularly the ocean), even this calculation is subject to a considerable degree of complexity and uncertainty.¹²

¹¹ The acidity of precipitation is influenced by complex interactions between sulfur oxides, related oxidation products, and NO_x .

¹² For example, the presence of CFCs could affect global warming not only directly through its greenhouse warming potential, but also indirectly by its impact on biota like nanoplankton – which in turn influence oceanic CO_2 uptake. Similarly, the degree of reliance on fossil fuels would affect CO_2 directly, and CO_2 absorption indirectly – via the effects of acid rain on forests and biomass.

The next link (2), between atmospheric concentration and temperature, is subject to much greater scientific uncertainty. The greenhouse effect itself, i.e. the trapping of incoming solar radiation, is subject to all kinds of additional factors that are highly complex. For example, if temperatures rise, and cloud cover increases, feedback effects involving increased reflection of incoming radiation will complicate the calculation of equilibrium temperatures.

The next linkage (#3) involves many different components. Some are relatively straightforward: for example, calculating the rise in sea level may be quite simple given assumptions about increases in mean sea temperature. Much more complicated are estimates of how precipitation patterns might change, especially the spatial and temporal distribution of rainfall. Perhaps of even greater concern in the developing countries will be the changes in the patterns of extreme weather events, to which they are particularly vulnerable.

If these physical effects are understood in general terms, quantifying the impacts on the flora and fauna is much more difficult (link #4). Suppose it were possible to predict the change in precipitation and temperature regime for some given region. What can be said about the shifts in vegetation patterns? While general northward shifts of vegetation and agricultural production zones can be predicted in general terms, quantifying the effect is quite difficult. What is the impact on biodiversity? On wetlands? On the water table? Clearly these are very difficult assessments to make.

Finally, in order to estimate the damage costs, one needs to be able to value these effects (link #5). Some valuation tasks will be relatively straightforward: for example, the cost of engineering structures to protect against sea level rise are relatively easy to establish, given the existing experience in this field (in such countries as the Netherlands). Other calculations will be more complex, but at least tractable: as for example, the calculation of increased cooling and decreased heating costs on the energy system, or the impact of increased irrigation pumping requirements associated with drier climates in some regions upon electricity demand. But a very large number of potentially important impacts are very difficult to value such as the impacts on forests, wetlands, and biodiversity.

Unique features

Beyond the degree of uncertainty, what makes the analysis of the climate change problem so different to other environmental analysis problems? The main reasons can be summarized as follows:

GHGs are stock, not flow pollutants:

Many pollution phenomena are relatively short-lived, such that the damages are closely related to the current rate of emissions. This is because the rate at which most pollutants are removed from the atmosphere is relatively rapid (say in the case of particulates by dry or wet deposition). Reducing emissions at major sources will likely have a relatively immediate impact. In the case of GHGs, however, the damages occur as a result of the total atmospheric concentrations at any one time, in other words, are related to the stock of the pollutant, not to the current rate of emissions.¹¹

Therefore, in the context of the climate problem, the global climate is a lagged function of the various greenhouse gases. At any point of time, these atmospheric concentrations (which are stock concepts) depend on the whole time path of emission of the greenhouse gases up till

¹¹ There are of course some exceptions, notably for radioactive wastes, which also have an extremely long life; thus the total environmental risk, and the scale of the disposal problem at any one time, is not so much dependent on current rates of production of nuclear wastes, as on the total stock.

the point of time under consideration. Similarly, an increase in current emissions of a greenhouse gas at any point of time will affect the atmospheric concentrations of this gas, and thus the climate, in all future periods.

To calculate the marginal environmental cost of increased current emissions of a greenhouse gas, one must first calculate the physical impact of such an emission increase on the future development of the atmospheric concentration of the gas. This will depend on physical characteristic of the gas, which affect how rapidly an increased atmospheric concentration depreciates. There are large differences between different greenhouse gases, with atmospheric lifetimes varying from e.g. 11 years for methane to more than 100 years for CO₂, N₂O and some CFCs.

Once the impact of current emissions of a greenhouse gas on future atmospheric concentrations has been calculated, one can in principle calculate the effect of the increase in current emissions on the future climate development. If one has specified a function which measures the monetary cost of climate change, one may thus calculate the incremental costs, and thus obtain a present value measure of the marginal cost of increased current emissions of a greenhouse gas.

It is clear from the description above that the marginal monetary cost of greenhouse gas emissions is a complex concept. Several assumptions of an economic nature must be made, such as the appropriate discount rate and the monetary costs of climate change for the whole future. In particular, the relative importance of different greenhouse gases is much more complex than some simple physical conversion into a common index. In the context of the climate problem, a reasonable definition of the importance of a greenhouse gas relative to, say, CO₂, is the marginal environmental cost of current emissions of this gas relative to the corresponding marginal cost of CO₂. It follows from the discussion above that the relative importance of GHGs depends on a number of economic assumptions which must be made.¹⁴

Inertia and irreversibility:

Since the emissions of GHGs in any one year represent a relatively small fraction of the total global stock, the system has great inertia. This means that even if all emissions went to zero, it would be decades, if not centuries, before the stock of GHGs become reduced significantly. Therefore, in effect, decisions about emissions reduction become effectively irreversible, at least over the 100-200 year timespan of interest. In other words, failure to reduce emissions in the short to medium term may be irreversible in the sense that once the effects of global warming become apparent, it will then be too late to do anything about it.

Global characteristics:

Most environmental pollution problems are local in scale.¹⁵ The benefits of emissions reductions generally accrue to the same geographic areas as would otherwise bear the costs. The damage associated with GHGs, however, are dependent upon the total global GHG concentration.

¹⁴ See e.g. Hoel and Isaksen (1993, 1994) for a further discussion and numerical calculations.

¹⁵ There are exceptions here as well, most notably the phenomenon of acid rain, which is largely a long-range phenomenon typically involving emissions in one country, and acid rain damage in another (e.g. emissions in the U.K. affect Scandinavia, emissions in the U.S. affect Canada, emissions in China affect Japan). However, to the extent that lake acidification completely destroys aquatic ecosystems, one could argue that at least some of the impacts are irreversible, although even here the impacts are generally of a fairly local nature. Long time periods may also elapse between the onset of acid rainfall, and to actual visible damage.

Therefore the distribution of benefits of emissions reduction is global, not local. Per contra, even a country that emits no GHGs would incur the damages of emissions by other countries:

Geographical distribution of impacts.

Unlike some other trans-national pollution problems, the impacts of global warming are likely to be highly concentrated among poorer nations, who lack the resources to protect themselves against sea level rise, extreme weather events, or desertification. By contrast, the impacts of acid rain tend to be concentrated in richer countries from emissions in poorer countries or regions (Japan from China¹⁶, Germany from E. Europe, the wealthy northeastern states of the US from Appalachia). These richer areas therefore have powerful incentives to promote emissions reductions programs in the source areas, including the provision of financial assistance.¹⁷ By contrast, except upon the basis of humanitarian solidarity and equity, it is unclear why countries like the US have any motivation to provide assistance to those who will bear the brunt of the expected cost of global warming.

Absence of actual impact data:

Unlike almost all other environmental externalities, there are no directly relevant data. All predictions of physical impacts are based entirely upon the predictions, judgments, and models of scientists.¹⁸ And there will be only one chance at collecting a data point – once (or if) global warming does occur, then of course the impacts will be known.

Non-linearity:

Global climate change is determined by complicated interactions involving a chain of non-linear linkages (i.e. GHG emissions - atmospheric concentration - temperature change - physical impact). Therefore, climate change phenomena and risks are likely to be much more non-linear than the relationship between conventional emissions and more local pollution.

¹⁶ For new data on emissions and acid deposition rates in Asia, see *Interim Report, International Collaborative Project on Acid Rain and Emissions Reduction in Asia*, World Bank, Asia Technical Department, September 1993.

¹⁷ For a discussion of the relationship between economic assistance for restructuring in Eastern Europe and assistance to guarantee desired environmental standards, see e.g. M. Amman *et al.*, *Economic Restructuring in Eastern Europe and Acid Rain Abatement Strategies*, *Energy Policy*, p.1187-1198, Dec. 1992.

¹⁸ In some cases laboratory experiments – such as growing plants in CO₂-enriched atmospheres – do of course provide some actual data for predictions.

4. Cost-Benefit Analysis in the context of global warming

In light of these unique characteristics of the global warming problem, what can we say about the suitability of CBA? How and under what circumstances can CBA make a contribution to the central questions now facing decision-makers: (1) by *how much* should emissions be reduced? (2) *when* should emissions be reduced? and (3) *how* should emissions be reduced?

The fundamental problem in applying CBA to the climate change problem follows directly from the chain of causality discussed above: while estimating the costs of emissions reduction involves the beginning of the chain, estimating the benefits (or the avoided damage costs) involves the very end of the chain. Since there is some level of uncertainty associated with each of the links, estimates at the last stage of the chain are subject to compound uncertainties which may be very large indeed.

Estimates of the marginal cost curve

A number of studies confirm the shape of the marginal abatement cost (MAC) curve shown on Figure 4.1 for the specific case of GHG emission reductions. London Economics (1992) reviewed eleven studies, and determined the "average" MAC curve as shown on Figure 4.1.¹⁹

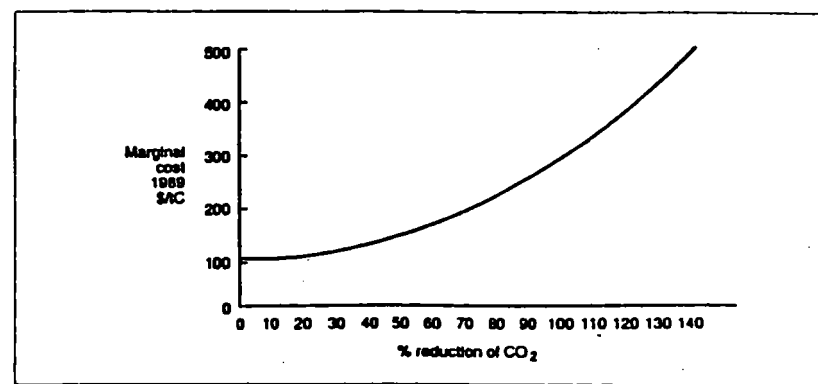


Figure 4.1: Marginal cost of CO₂ reduction (from GEF, 1992, p.31)

Such MAC curves have been derived for many industrialized countries, but for only few developing countries.²⁰ On Figure 4.2 we show the cost for the U.K., as estimated by Jackson (1991). The curve is derived by a rank ordering of the individual measures considered by cost per ton of CO₂ saved (the height of each block), with the width of each block representing the

¹⁹ The most comprehensive review of cost studies is that by UNEP, *Greenhouse Gas Abatement Costing Studies*, UNEP Collaborating Center on Energy and Environment, Riso National Laboratory, Denmark, August 1992.

²⁰ A recent UNEP review on GHG abatement costing studies concluded "...the state of abatement costing studies in developing countries is wholly inadequate even to draw preliminary conclusions concerning possible costs and the impact of different abatement options. It is a body of analysis which is only just beginning, and which may take many years to mature towards consensus even on very rough estimates and understanding of the key issues (UNEP, *op.cit.*, p. 66).

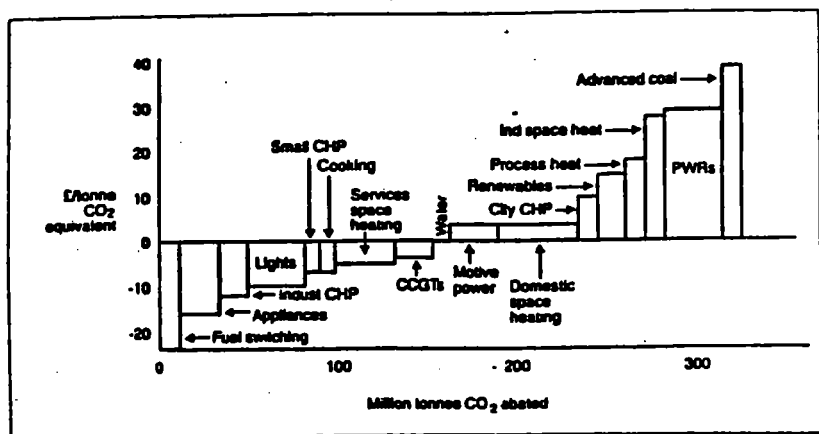


Figure 4.2: The marginal cost curve for the U.K.

tons of CO₂ so saved. The shape of the MAC curve, when smoothed, is indeed of the type indicated on Figure 4.1. Generally, these studies rely on known or near-term technical options, and ignore effects due to joint products, economies of scale, and capacity building, that might reduce the upward slope of the cost curve.

What is interesting in these (and other studies²¹) is the significance of "below the line" options (i.e. MAC is negative but still upward sloping). These are measures that appear to have negative costs associated with them – in other words, when these options are implemented, both costs and emissions go down, relative to the reference case.²² Compact fluorescent lighting, other energy efficient devices, and demand side management measures typically fall into this category, and in developing countries, measures such as reducing T&D losses, or instituting vehicle maintenance programs, also appear here. These, then, are measures that should be implemented in a least cost energy development strategy, even in the absence of any desire to reduce GHG emissions. The fact that they are not implemented reflects either market failures, or other factors, such as high transaction cost (which might exceed the potential benefits)²³

²¹ See e.g. J. Moreira et al., 1992 for Brazil; S. Sitnicki et al., Opportunities for Carbon Emissions Control in Poland, *Energy Policy*, 19,10, p.995-1002, 1992; or P. Meier, M. Munasinghe and T. Siyambalapiita, *Energy Sector Policy and the Environment*, World Bank Environment Department, 1993, for Sri Lanka.

²² Unfortunately there is some confusion in terminology here. Some (e.g. London Economics, *Economic Costs of Carbon Dioxide Reduction Strategies*, Global Environment Facility Working Paper Series 3, Washington, DC, 1992), use the term "no regrets" to describe policies for which MB > MAC, i.e. for which the marginal benefits exceed the marginal costs. Others use the term only where MAC < 0, i.e. to those options that are "below the line" in the empirical cost curves of the type shown on Figure 4.2. However, since on both the cost and the benefit side there will be some netting out (e.g., to account for joint costs and benefits), the criterion MAC < 0 is arbitrary, whereas MAC < MB is well defined.

²³ The fact that such "no-regrets options" are in fact observed is much debated. What may be calculated as monetary benefits need not necessarily be regarded as benefits to decision-makers – there may be other, non-monetary costs involved. The huge subsidies given to European agriculture illustrate the point that more than monetary benefits might be involved. In the case of developing

This issue highlights a practical problem for the Global Environment Facility (GEF). The GEF has been set up as the funding mechanism, on an interim basis, to provide financial resources needed by developing countries to meet the "full incremental costs incurred" in complying with their obligations under the Convention on Global Climate Change.²⁴ If the GEF is to fund the "incremental costs" of GHG reduction measures, this presupposes that a baseline can be unambiguously defined, against which such incremental costs are to be measured.²⁵ But under such a definition, should demand side management programs which have negative incremental costs – such as energy efficient lighting – be funded by GEF?²⁶

The marginal benefits curve

It follows from the discussion of the previous section that the level of uncertainty in benefits is much greater than the level of uncertainty in the cost curve. The practical implication of this, depicted in Figure 4.3, is that the optimum point of emissions reduction is also subject to significant uncertainty (indicated by points A, B, and C): whether the marginal benefits curve is MB1, or MB2 or MB3 has a much greater impact on the location of the optimum point of emissions reduction than the much smaller uncertainties in the marginal cost curve. Therefore, with such wide uncertainty about the economic optimum, CBA may not be very helpful. On the other hand, a "precautionary" level of emissions reduction, at P, has a very high probability of at least meeting the criterion that MB > MC.

In fact, there exist few if any estimates of the benefits curve, and most of the estimates that do exist are not much more than single point estimates for some presumed level of GHGs in the atmosphere. Well known for the US is the work of Nordhaus, who begins by classifying the

countries, the unavailability of finance may constrain the ability to implement some of these options. For example, until recently, obtaining finance through export credits for power generation expansion has been much easier than financing energy efficiency measures.

²⁴ These methodological problems have been recognized by GEF, who has initiated a research program to find an operational approach for measuring and agreeing upon full incremental costs within the context of the Climate Change Convention: the so-called PRINCE study (Program for Measuring Incremental Costs for the Environment). See K. King, *Issues to be Addressed by the Program for Measuring Incremental Costs for the Environment*, Global Environment Facility, Working Paper 8, Washington, DC 1993.

²⁵ Moreover, another problem here is that the concept of "least cost" as well as the integrated planning process to achieve it, may be quite complex (see e.g. M. Munasinghe, *Energy Analysis and Policy*, Butterworths Press, London, UK, 1990; P. Meier, *Power Sector Innovation in Developing Countries: Implementing Investment Planning under Capital and Environmental Constraints*, *Annual Review of Energy*, 15, pp.277-306, 1990; or E. Crousillat, *Incorporating Risk and Uncertainty in Power Sector Planning*, Industry and Energy Department Working Paper, Energy Series Paper 17, World Bank, Washington, DC, 1989). Such a solution, typically obtained by fairly sophisticated optimization models, may be "least cost" only for a very narrow band of input assumptions; and if these assumptions prove to be different, then an investment program predicated upon the "least cost" plan may ultimately be distinctly non-optimal.

²⁶ In the words of King, *op.cit.*, "...How can the adoption of apparent win-win solutions be stimulated? Such solutions are sometimes referred to as negative incremental cost projects because they are economically viable in their own right. The dilemma arises because these projects are often not being funded. On the one hand, if the GEF restricts itself to those projects that have positive incremental cost while the bulk of negative incremental cost options remains unfunded, it risks becoming irrelevant to the main solution to the global environmental problem. On the other hand, providing grant finance for economically viable projects effectively makes a net transfer to the country, which is not the purpose of new and additional funding, worse, it provides a perverse incentive to potential recipient countries to delay economic reform. (p.17)"

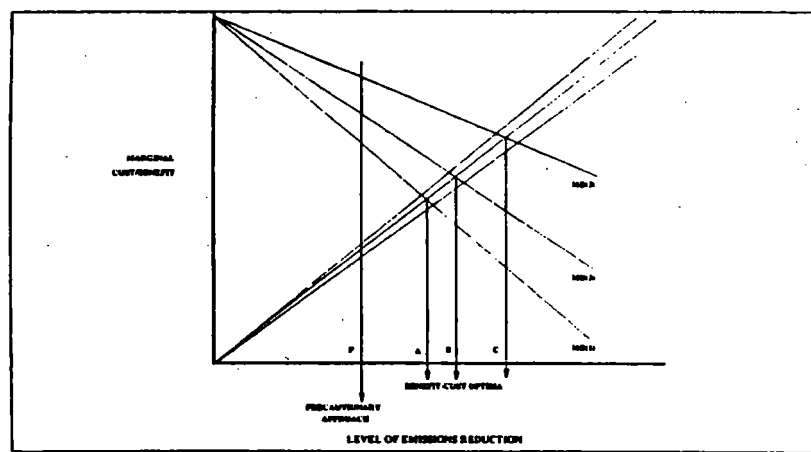


Figure 4.3: Uncertainty in the benefits curve.

components of economic activity (national income) into three groups: (1) those potentially seriously impacted; (2) those with moderate potential impact; and (3) those having negligible effect.

For the sensitive sectors, Nordhaus then goes on to estimate the impacts associated with a doubling of CO_2 in the atmosphere (Table 4.1). He concludes that in fact damage from sea level rise is the most certain major impact, since estimates on the most sensitive sector, agriculture, range from a significant net cost to a significant net benefit. Overall, the central point estimate of impact is 0.26% of national income.

The implication is that countries in which manufacturing and services are the dominant activities are not likely to be greatly affected in overall macro-economic terms (e.g. in the U.S., only some 3% of GDP is in the farm and forestry sector).

Whether this type of approach in fact captures all the relevant costs is of course subject to debate, since a whole range of costs like damage due to extreme weather events and potential non-market impacts, such as loss of biodiversity, is ignored. Moreover, it is entirely unclear whether some of the areas that have been included in Nordhaus' analysis have been given adequate attention.²⁷ For example, municipal water supply, which presently accounts for a very small part of national GDP, may be potentially extremely sensitive to small changes in climate in the western US — where even under present conditions costs are growing very fast.²⁸ However, as shown on Table 4.2, other estimates of the impact of global warming, including those which attribute much larger impacts to wetlands, species loss etc, do not result in significantly larger losses of output.

²⁷ For a critique of Nordhaus' estimates, see e.g. Williams (1993).

²⁸ A study of the impacts of global warming in California points to the severe problems that might be encountered in that state. Because of changes in the distribution of rainfall, resulting in winter runoff and lower spring runoff, water supply from reservoirs in the Central Valley Basin would significantly decrease. See EPA, *The Potential Effects of Global Climate Change on the United States, Report to Congress*, Office of Policy, Planning and Evaluation, Washington, DC, 1989.

Table 4.1: Estimates of the impact of global warming on the US GDP

	% of GDP	% of total	cost billion 1981 \$
Total national income			
Potentially severely impacted		3.1	
farms	2.8		10.6 to -9.7
forestry, fisheries, other	0.3		small
Moderate potential impact		10.1	
construction	4.5		negative
water transportation	0.3		?
energy (electric, gas, oil)	1.9		
electricity demand			1.65
non-electric space heat			-1.16
water and sanitary	0.2		positive?
real estate (land rent)	2.1		
loss of land			1.5
protection of sheltered areas			0.9
protection of open coasts			2.8
hotels, lodging, recreation	1.1		?
Negligible effect		86.8	
mining	1.9		
manufacturing	24.1		
other transport & communications	5.5		
finance, insurance	11.4		
trade	14.5		
other services	13.5		
government services	14		
rest of world	2.1		
Total impact			6.2

Source: W. Nordhaus, *Economic approaches to greenhouse warming*, in Dornbusch and Poterba (Eds) *Global Warming: Economic Policy Responses*, MIT Press, Cambridge, MA, 1991.

Table 4.2: Estimates of the impact of global warming

	U.S.			Global		
	Nordhaus	Cline	Fankhauser	Other	Fankhauser	Other
Heavily affected sectors						
agriculture	1	15.2	7.4	1.2	39.1	12.3
coastal areas	10.7	2.5	2.3			
energy	0.5	9				
Other sectors						
wetlands and species loss		7.1	14.8			
health and amenities		8.4	30.3			
other	38.1	11.2	12.1			
total	50.3	53.4	66.9			
total as % of output (GDP)	1	1.1	1.3		1.5	2.8(a)

Blanks denote not available. (a) from Nordhaus' survey of experts. Sources: Nordhaus (1991), Cline (1992), Fankhauser (1992); for agriculture under "other" Reilly and Hohmann, 1993.

Source: Nordhaus (1994), p. 369.

Despite the suggestion that the economic impact of global warming on the industrialized countries is quite small, Nordhaus, as well as others, are quick to concede that such results may not apply to developing countries, where typically much larger shares of national income

are in agriculture, and much of it in subsistence farming in marginal areas where even small changes in climate may have devastating effects, and where the ability of the farming population to adapt may be very small indeed.²⁹ The types of human settlement most vulnerable to climate change are concentrated in developing countries, including low-income communities, residents of coastal lowlands and tropical islands (such as coastal Bangladesh, or the Maldives), populations in areas already significantly affected by desertification, and the urban poor in squatter settlements³⁰.

Unfortunately, to date, most of the discussions of impacts of global warming on the developing countries have been qualitative in nature,³¹ and there is an urgent need for more quantitative estimates for developing countries. According to a recent GEF survey of country studies³², there are now almost as many studies underway on effects as on mitigation, but it is difficult to ascertain how many of these studies, most of them now underway, will result in the sort of quantitative information necessary to construct an impact cost curve. Certainly none of the studies and papers published to date for developing countries contain quantitative estimates of the type derived by Nordhaus for the US.³³

Measuring costs and benefits

Nordhaus' work on the benefit (avoided cost) side, and much of the work on the cost side, assumes that the relevant measure by which to evaluate options is loss of GDP. This raises a separate set of questions about the extent to which GDP, (or loss of GDP growth) is the appropriate measure.³⁴ It is well established (Weitzman, 1976, Brekke, 1994) that GDP is not

²⁹ This is likely to be true even though higher CO₂ concentration itself may promote plant growth.

³⁰ For further discussion, see e.g. J. T. Houghton *et al.* (Eds). *Climate change--The IPCC Scientific Assessment*, World Meteorological Organization and the United Nations Environment Program, Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 1990; or L. B. Lave and K. Vickland, *Adjusting to Greenhouse effects: the Demise of Traditional Cultures and the Cost to the USA*, *Risk Analysis*, 9, 283-291, 1989. However, as also noted by Nordhaus (1994), the fertilizing effect of atmospheric CO₂ is a particularly strong mitigating factor for Agricultural nations, particularly where water is a limiting factor: while the extent and quantitative importance of CO₂ as a fertilization agent are controversial, the balance of the evidence is positive (Nordhaus, 1994, p.369).

³¹ see e.g. the discussions of P. Glick, *Climate Change and International Policies. Problems Facing Developing Countries*, *Ambio*, 18, 6, p.333-339, 1989; or R. K. Pachauri, *Global Warming: Impacts and Implications for South Asia*, Tata Energy Research Institute, New Delhi, 1991).

³² J. Fuglestad *et al.*, *A Review of Country Case Studies on Climate Change*, Global Environment Facility, Working Paper 7, Washington, DC, 1994. This report identifies 39 studies (or elements of studies) focused on inventories of GHGs, 48 studies of effects, and 46 studies on mitigation.

³³ For example, in a report prepared by the Tata Energy Research Institute for the India Ministry of Environment and Forests, the Chapter on Adaptive Strategies for India in the Perspective of Climate Change, which elaborated the impacts associated with given levels of sea level rise and mean temperature, was entirely qualitative in nature, and no cost estimates were attempted. (TERI, *Report on Global Warming and Associated Impacts*, Report to the Ministry of Environment and Forests, January 1991). Similarly, neither Volume on Global warming published by the Asian Energy Institute (Pachauri and Behl, (Eds), 1991), nor the country studies conducted by UNEP (Reported in UNEP, 1992) contain any country specific estimate of costs associated with specific levels of GHG accumulation in the atmosphere. ADB is currently sponsoring a multi-country project in Asia that is attempting to establish costs of potential effects.

³⁴ There are several related issues. For example, should one use nominal exchange rates,

a welfare measure per se, but rather a convenient way to aggregate goods and services which clearly contribute to welfare.

Thus it is well recognized that GDP is an imperfect proxy for social welfare. One recent Norwegian study (Alfsen, Brendemoen and Glomsrod, 1992) showed significant differences in cost-effectiveness of different policy options for GHG emissions reduction policy when consumer surplus effects were also included in the analysis³⁵. These effects have found to be significant in developing countries as well, as shown by Meier *et al.* (1993) in the case of Sri Lanka (see Table 4.3).

Table 4.3: Impact of welfare losses of GHG abatement options in Sri Lanka
(in \$/ton of avoided carbon)

	no coal	wind	CFL
supply cost impact	16	67	-472
consumer impact	10	66	-66
total	26	131	-538

source: Meier, Munasinghe, and Siyambalapitiya, *op. cit.*, 1993.

notes: negative numbers indicate a benefit
CFL= compact fluorescent lighting

Of course, the magnitude of such impacts is a function of how much of the technology is adopted, how soon, and what discount rate is used. The effect of a single 25Mw wind plant will obviously be much less than if a 300 Mw wind farm displaces an imported coal plant in the near-term. Generally, what these results do underscore is the need for great caution when interpreting the so-called costs of GHG-emission reductions attributable to specific technologies.

Equally important are the concerns over the extent to which conventional measurements of GDP growth take into account the depletion of natural resources ("Green Accounting"). For many developing countries this is a particularly important issue, and there is a growing literature suggesting that conventional accounting substantially overstates GDP growth: the corollary is that estimates of GDP impacts of climate change that fail to take into account changes in the rate at which natural resources are depleted, or in environmental impacts, may be understating the true effect.³⁶

Some of these problems are evident from the numerical estimates. On Figure 4.4 we display the results of recent studies of the impact of emissions reduction strategies on loss of GDP³⁷. As is evident, these impact estimates show considerable variation: even so, none of

trade-weighted rates, or purchasing power parity rates in making cross-country comparisons of costs or impacts?

³⁵ Consumer surplus impacts have been vigorously debated in the United States in terms of how to evaluate the costs and benefits of demand side management (DSM) programs. For example, Hobbs (1991) shows that some programs may have positive benefits under a simple "least cost" criterion from the utility perspective (avoided supply costs exceed program costs to the utility), but have negative benefits when changes in consumer surplus are taken into account.

³⁶ The question of "green accounting" is one of valuing and aggregating marketable and non-marketable goods. The many different proposals for "green accounting" reflect the difficulties involved. Rather than speculate about valuation, or poorly founded proxies for non-marketable goods, MCA provides an alternative approach.

³⁷ These results are for studies that estimate both emissions reductions and GDP impacts relative to some baseline, i.e., relative to the trajectory of emissions in the absence of the policies followed. For many countries, particularly the developing nations, even significant reductions from such baselines

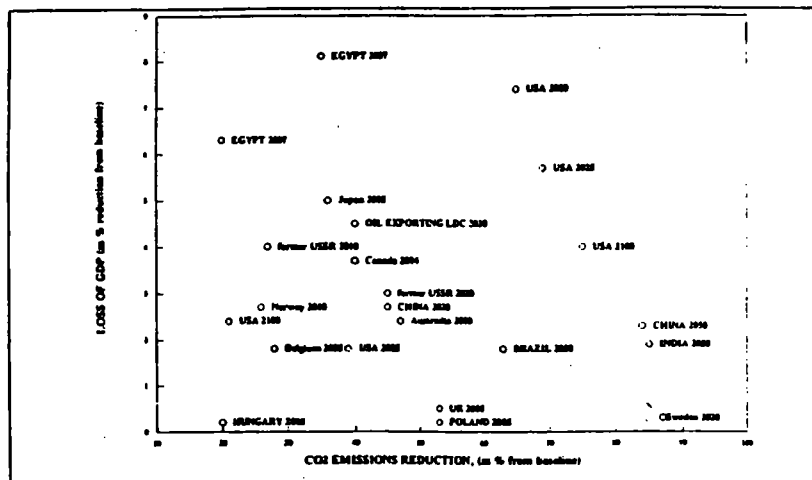


Figure 4.4: Impact of GHG emissions reductions on GDP

these estimates reflect "green accounting", and only one takes into account joint products.³⁸ Most of these studies are national studies. Many researchers argue that unilateral action by the US or by OECD countries are likely to be less effective than global action, and that unilateral actions are likely to exaggerate the impact on GDP.³⁹ However, these studies also neglect the benefits of the development of advanced technologies in the market economies, which could then be more quickly adapted in the developing world.

The joint products problem

A related question concerns the joint benefits and costs of emissions reduction. Options that reduce GHG emissions may also provide significant changes in other pollutants whose impacts are of a quite different scale. For example, the substitution of renewable energy technologies for coal will reduce not just CO₂ emissions – a *global* benefit – but also SO₂ and particulate emissions that bring a reduction in *local* environmental damages. On the other hand, the increased use of renewable energy technologies (such as hydroelectric generation), which also reduce CO₂ emissions, may also impose new and different local environmental costs (such as loss of biodiversity associated with reservoir inundation).

Estimates of the importance of joint benefits and costs vary widely (in part because valuing the costs and benefits of other environmental impacts may be subject to similar

may still imply increases in the absolute quantity of GHGs emitted. Other studies report results in terms of GHG emissions in some future target year, relative to emissions in some prior year (e.g. 2010 emissions 10% less than 1990 emissions).

³⁸ S. Glomsrød, H. Vennemo, and T. Johnson, *Stabilization of Emissions of CO₂: a Computable General Equilibrium Assessment*, Central Bureau of Statistics, Discussion Paper 48, Oslo, Norway, 1990.

³⁹ For further discussion see UNEP, *op.cit.*, p.72. Studies that have examined the question of unilateral v. multilateral approaches include Proost and van Regemorter (1990) for Belgium, and Edmonds and Reilly (1983) and Rutherford (1992).

Box 1: Valuation of joint products in the U.S.

The importance of joint products can be gauged at least in part from the practices of some regulatory commissions in the United States. A growing number of these now require that electric utilities take into account the value of air emissions in their cost-benefit analysis of alternative supply and demand side resources. The table below shows the current monetary values for some States.

Externality values for air emissions, in \$/ton

	CO ₂	NO _x	SO ₂	particulates
New York	1.1	1,832	832	333
Massachusetts	22	720	1,700	4,400
Nevada	22	6,800	1,560	4,180
California (PG&E)	26	7,105	4,060	2,380

That the values assumed for CO₂ vary by an order of magnitude is to be expected, given the uncertainties on the benefits side of a unit reduction in emissions. But the wide differences in values for other emissions do reflect strong locational differences. Unlike for GHG, for most other air pollutants it *does* matter *where* they are emitted – indeed, values for the Los Angeles area for NO_x emissions are even larger than those shown on the table, reflecting the seriousness of the smog problem in that air basin. The point is that when joint products of GHG emission options are also included in the analysis, then *location* does play a role. Phrased differently, if one is going to reduce GHG emissions, it should be done in those places where the joint benefits of reducing related emissions is highest.

It should be noted, however, that while the CO₂ values are based on avoided costs (e.g. in Massachusetts and Nevada based on the cost of planting trees on otherwise unforested land), the externality values for the other pollutants are based on control costs, the conceptual basis for which is very weak: it is obvious from Figure 2.2 that using the abatement cost function as a proxy for the damage cost function, even in the vicinity of some health-based standard, is likely to involve substantial error. The use of damage control costs as a proxy is justified by these regulatory commissions solely on the basis that damage cost estimates are highly uncertain.

However, in one or two cases we do have consistently estimated damage cost-based externality values. On the table below we show that using estimates derived by the California Energy Commission, for every dollar in benefits resulting from the reduction of CO₂ emissions, there is another \$3 resulting from the reduction of conjoint pollutants. Whatever the uncertainties that may surround the actual values used, it is certainly a reasonable conclusion that joint benefits will significantly affect the overall cost-benefit assessment of GHG.

Estimated benefits of reducing electricity demand by 1 Mwh

	\$/ton	emission rate (lbs/mwh)	total benefit \$
CO ₂	26	1,820	23
joint products			
NO _x	14,483	6	43
SO ₂	7,425	6	22
TSP	57,620	0.3	9
total joint products			74

Emission rates based on a notional, new coal-fired plant meeting new source performance standards (NSPS). Externality values for NO_x, SO₂, and particulates based on 1992 California Energy Commission Report (Hersh, Barakat and Chamberlin, California State Summary, EPRINET Environmental Externalities Clearinghouse).

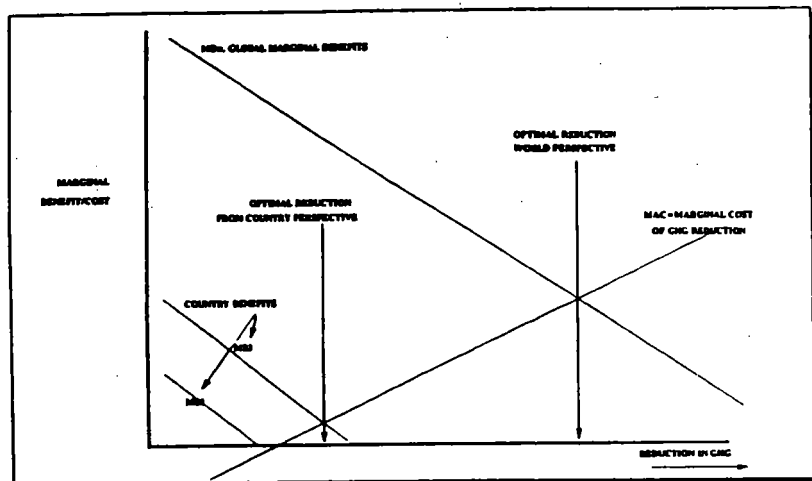


Figure 4.5: The marginal cost and benefits curve for an industrial country

difficulties of valuation and scientific uncertainty as for GHG emissions), but most lie in the range of 1 to 10\$ of additional benefits for every dollar of benefit from GHG emission reduction. (see Box 1). A recent Norwegian study (Alfsen, Brendemoen and Glomsrod, 1992) indicated that when the joint products of carbon reduction were taken into account (reduction in environmental damages to forests and lakes, health damages, reduced traffic congestion, road damage etc.), then such benefits go a long way toward compensating the economic loss measured as reduction in GDP.⁴⁰

Adding the benefits of reductions in conjoint pollutants to the MB measure is one possibility. The other is to subtract these benefits from the MC measure. Since most of such benefits go to the country that bears the costs of abating the CO₂ emissions, while the benefits of less CO₂ emissions go to all countries, it follows that the preferred approach is to adjust the marginal cost curves.

The aggregation problem

We now turn to the matter of implementing policy. Consider first Figure 4.5, which depicts the situation faced by some country. Its marginal cost curve is upward sloping, in the manner discussed above; it begins with negative values (the "no regrets" or "win-win" options) again in the manner indicated earlier.

Suppose Figure 4.5 depicts the situation for an industrialized country, say the US. Suppose that indeed Nordhaus is correct in his estimates that the benefits to the US are rather small. If MB₁ were true, then the optimal policy would be only to implement the win-win policies – demand side management, more efficient end-use devices, economically efficient pricing, and the like. If MB₂ were true, for the US perspective, then perhaps only small

⁴⁰ For example, in one alternative (the "Treaty Alternative"), loss in GDP was estimated at 3.1 billion Kroner, and the loss of private consumption at 2.6 billion; however joint product benefits were estimated at 2.4 billion (with a range of 1.0-3.8 billion). (Alfsen, Brendemoen and Glomsrod, 1992, p.28).

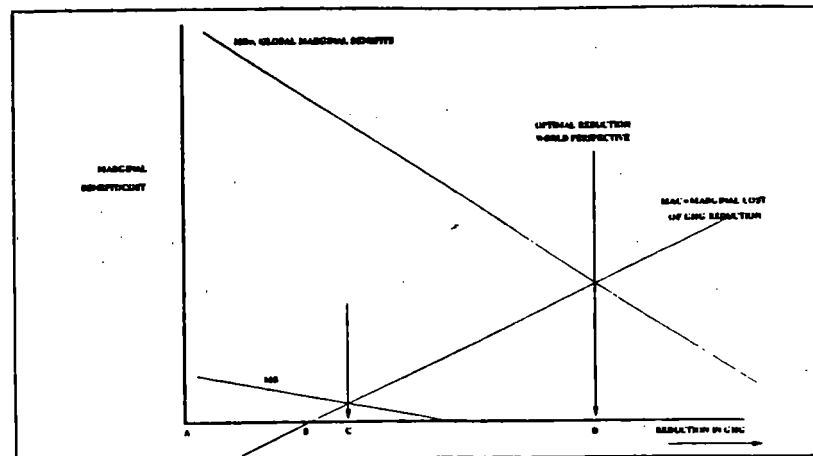


Figure 4.6: The marginal cost and benefits curve for a developing country

emissions reductions are warranted. We assume, of course, an appropriate adjustment for the valuation of the benefits of the reduction of joint costs.

However, the benefits to the rest of the world of emissions reductions are likely to be much higher: and hence the curve MB₂ lies as shown, far above the MB₁ and MB₃ curves. Therefore, when global benefits of emission cost reductions are taken into account, the optimum level of emissions reduction shifts to the right, as shown. How one persuades decision-makers in the US (and in other industrialized countries) to take a global perspective is the main question.⁴¹

Consider now the situation for a developing country (Figure 4.6). Again the global benefits curve lies far above the curve for an individual country. Evidence from empirical studies suggests that a far larger portion of the MC curve is in the no-regrets zone. Several multi-country studies point to the same result.⁴²

⁴¹ In Figure 4.5 we have drawn, for clarity, only a single marginal cost curve (MAC). It is quite possible, however, that different countries will also have different marginal cost curves (although the differences in costs are likely to be smaller than the differences in benefits).

⁴² For example, studies by Burgess (1990) and by Larsen (1993) address the impact of eliminating price subsidies: they estimate the level of reduction in GHG emissions by application of assumed price elasticities to the difference between the subsidized and unsubsidized price. Burgess uses the difference between actual average cost of electricity and the estimated long run marginal cost (LRMC), applies an assumed long run price elasticity of -1, and estimates the reduction in GHG emissions for eleven countries, including the USA, China, India, and some small developing countries such as Tanzania and Peru. Not surprisingly, the bulk of the total carbon emission savings of 124 million tons/year (mtpy) come from coal fuel savings, of which India accounts for 11.9 mtpy, China 26.6 mtpy, and the USA 85.4 mtpy. Larsen does the same analysis but from the perspective of fuel prices, applies estimated own- and cross-price elasticities for the different fossil fuels to the difference between an appropriately adjusted border price and the domestic subsidized fuel price, and, more significantly, includes the countries of the former USSR and Eastern Europe. In this analysis, the former USSR (917 mtpy) and Poland (105.2 mtpy) dominate the results; indeed, the combined estimated impact in India (54 mtpy), and China (45.4 mtpy) together is less than that for Poland.

In the case of developing countries, it is the GEF mechanism that provides the means for shifting the level of emissions reduction undertaken by any specific country to the right. But in what range does the GEF mechanism operate? Conceptually, it should operate in the range CD, i.e. provide funding only beyond the optimal level from the country perspective. But since the MB curve is so difficult to determine, operationally, an easier definition is for GEF to operate in the range BD; i.e., from the conventional "least cost" point that would normally apply, and in which any benefits, even locally, from GHG reductions are simply taken as zero. For example, wind plants would not normally lie in the least cost expansion path for an electric utility (if environmental externalities are valued at zero); GEF provides the mechanism to fund such technologies. Yet in fact, GEF has also funded projects in the range AB – such as the energy efficient lighting project in Mexico.⁴³

The difference between optimal level of reduction from the national perspective, and that from the global perspective, lies at the heart of the practical problem of implementation. A related but different issue – related to equity – concerns one of the premises of CBA, namely that sunk costs and past actions are not relevant. Yet developing countries argue that in the case of the climate change problem, past emissions are relevant, because it is the industrial countries, not the developing countries, that have accounted for the bulk of the man-made GHGs present in the atmosphere.⁴⁴

Systemic evaluation. The above results for Sri Lanka also points to the importance of systemic evaluations: the cost per ton of avoided emission for both wind and the no coal option are much lower than those estimated by others, for the exact same technology (see Table 4.4). The answer, of course, lies in the fact that the incremental cost of, say, wind power, depends upon what technology is being substituted: and these will be very different from case to case. For example in Sri Lanka, imported coal baseload plants largely determine the future system expansion cost. This is much more expensive than in India, which has available relatively large quantities of low cost domestic coal. Similarly in the generic cost estimates made by GEF for no coal options, the presumed substituting fuel is domestic oil or gas, not imported oil (as is the case for Sri Lanka). The point is that there likely exist very large, country-specific variations in the estimates of the cost of GHG emissions abatement through given technologies. Joint costs and benefits that are local in nature will very likely vary even more from place to place.

⁴³ GEF has recently introduced the term "Type I project" for those in which operate in the range AC (i.e. for which national economic benefits are greater than national costs), and "type II project" for those in the range CD, (i.e. for which national economic benefits are less than national economic costs, but the global benefits are such that the project is justified under GEF criteria). For further discussion, and arguments for why GEF should give priority to type II projects, see e.g. D. Anderson and R. H. Williams, *The Cost-Effectiveness of GEF Projects*, Global Environment Facility, Working Paper 6, Washington, DC., 1993.

⁴⁴ See, e.g., M. Munasinghe, Sustainable Energy Options for Developing Countries, *World Energy Council Journal*, 1, Dec. 1991, p.69-87.

Table 4.4: Comparisons of cost estimates for CO₂ abatement.

	study type	wind	no coal
Sri Lanka	systemic, single 300Mw windfarm	67-131	16-26
GEF	generic	116-223	45-89
India	supply cost	150-600	

Sources: For Sri Lanka, Meier, Munasinghe and Siyambalapitwa, *op. cit.*; for India J. Hossain and C. Sinha, *Limiting CO₂ emissions in the power sector of India* *Energy Policy*, Oct. 1993, p.1028. Generic estimate from London Economics, *Economic costs of carbon dioxide reduction strategies*, GEF Working Paper Series 3, Washington, DC, 1993.

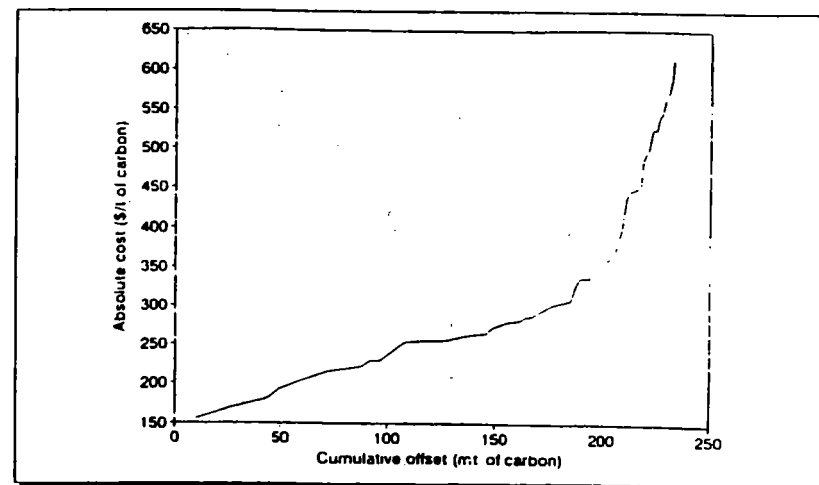


Figure 4.8: supply cost curve for windfarms in India

source: J. Hossain and C. Sinha, *Limiting CO₂ emissions in the power sector of India* *Energy Policy*, Oct. 1993, p.1028.

another way of making the same point is by noting that single point cost estimates for many technologies can be quite meaningless, because the supply curve for even an individual technologies is not flat. For example, in the previously presented GHG emission cost curve of Figure 4.1 (for the UK), "renewables" is shown as a single block, with a single marginal cost. Yet as shown in a recent study of wind and hydro for India⁴⁵, the supply curves have the expected classical upward sloping shape as illustrated on Figure 4.8 for the supply cost of windfarms in India. Such static cost curves neglect the counter-argument that in a more dynamic analysis, cost may decline due to economies of scale and technological advances.

⁴⁵ J. Hossain and C. Sinha, *Limiting CO₂ emissions in the power sector of India* *Energy Policy*, Oct. 1993, p.1028.

5. Issues

Risk, uncertainty and irreversibility

Our knowledge about how anthropogenic emissions of greenhouse gases affect global temperature, what kind of effects a change in global temperature may have, and how efforts to mitigate climate change may work is clearly restricted. How different greenhouse gases react in the atmosphere are not fully understood, and exact predictions of the average increase in global temperature will have different regional effects which are exceedingly difficult to foresee, even if the effect on the average temperature were taken as given. There is also considerable uncertainty about the economic and social effects of abatement measures, which are decisive for the costs and benefits of the measures.

One cannot, therefore, evaluate climate measures without taking these uncertainties into account. On the other hand, acknowledgment of vast uncertainties should not lead to an inert attitude, but rather to develop rational strategies for how to act under uncertainty. Economic analysis under uncertainty aims at developing strategies for decision makers that face uncertainties in their future costs and benefits. The uncertainty in the outcome of a variable is often described by a probability attached to each possible outcome. In some cases the probability distribution is objectively presented, in which cases one normally talks about risk. More often, subjective probability distributions are assumed, in which cases one talks about uncertainty.

The attitude towards risky outcomes is often expressed in terms of a risk premium, which is the minimum compensation required to accept a lottery with expected return x to a certain return of x . Such a premium may be required because the decision maker prefers certain to uncertain outcomes, but may also occur if the net benefit of his investment is non-proportionate in quantity. For instance, suppose a country commits itself to reduce emissions by 100 tons, and considers two alternative measures. One alternative reduces emissions by 100 tons with certainty. The other measure has a 50 percent chance of reducing them by 100 tons. Even if the expected reductions are equal, it is evident that a decision maker will prefer the certain alternative unless the uncertain alternative is considerably less costly, as there is a chance of having to impose additional measures if unlucky. Assessments of the uncertainty involved in the analysis of climate change may therefore be of great importance to decision making.

However, given the uncertainty it is also important to emphasize that some actions will be less attractive than others. The mirror of the above argument is that some actions may be acceptable even with negative net expected benefit if they reduce the uncertainty. One way to do so is to spread the risk among several measures. Then, if one fails to meet its expected target, another may satisfy the achievements that were expected. The total risk would thus be lower than if all efforts were concentrated on one single measure.

One is scarcely able to account for all the uncertainties involved when analyzing climate change. In some cases it may be equally difficult to assess a probability distribution of a variable as a single expected estimate. Ignorance about certain effects of a measure indicate that they should be left out of the analysis. However, CBA may be of great help to decision making even when limited to effects on which reasonably well-founded value-estimates can be provided.

One issue that has attained a lot of interest in the literature of environmental economics is the problem of irreversible decisions under uncertainty. The reason is that environmental effects, such as climate change are regarded as irreversible. If the effects turn out to be worse

than expected, the world is stuck with a permanent, perhaps unwanted, climatic change, which clearly is worse than if the climate could be reestablished after such a change.

Provided that the CBA is worked out correctly, however, the cost of irreversible effects would be included. This requires a vast amount of information, such as how the uncertainty evolves over time. Such information, is rarely available, but we may assume that increased knowledge about climate change will narrow the range of uncertainties in the future. If so, it has been shown that measures causing irreversible effects have an extra cost, called quasi option value. This value can be interpreted as the value of keeping future options open, and suggest that decision makers follow flexible strategies when faced with uncertainty.

The strategy that leaves most future options open is, however, difficult to determine. Investing in abatement of climate change opens possibilities for increasing emissions at a later stage if the effects turn out to be less serious than expected. On the other hand, it reduces the potential use of adaptation. In addition, it is difficult to predict the effect of increased knowledge, especially whether the outcomes become more certain. When dealing with many of the effects of climate change, ignorance is perhaps a more appropriate concept than uncertainty. Increased knowledge may change ignorance to uncertainty, but the range of possibilities will not necessarily narrow for that reason.

In applying CBA to the global climate change problem, and in particular to the evaluation of alternative policies to optimize net benefits, there are six major sources of uncertainty that need to be considered:

1. Uncertainty over the actual rates of emission. All of the many studies cited earlier make assumptions about current and future rates of emissions in some "business-as-usual" case as a starting point. Current projections of CO₂ emissions from fossil fuel use may be reasonably well known, but the level of uncertainty increases as one moves to levels of possible fossil fuel use in the more distant future, the impact of deforestation, or to other GHGs such as methane.⁴⁶
2. Uncertainty over the costs of emissions reduction. Again there are significant differences between estimating the costs in electric utility systems (relatively well known for conventional technologies) and those elsewhere, particularly for reforestation.
3. Uncertainty about scientific linkages. As already noted in section 3, there exists a chain of scientific uncertainty (see Figure 3.1). The extent to which these uncertainties can be resolved by further research is itself subject to uncertainty (especially in light of the previously noted fact that by its very nature, *ex ante* verification of models by actual data is impossible). Thus it is unclear that similar arguments invoked in the context of other environmental problems have validity for global climate change. For example, the argument that further research was necessary on an understanding of atmospheric chemistry, or of the chemistry of lake acidification, or of the exact nature of the damage mechanisms on forests, before very costly efforts are undertaken to control SO₂ and NO_x emissions, did at least have the merit that data on the actual damage of acid rain could be found.
4. Uncertainty in valuing the costs and benefits of the physical impacts. Here there may exist quite large variations in the level of uncertainty: for example, evaluating the cost of protective dikes to protect against sea level rise, or of estimating the opportunity cost of inundated land is subject to significantly less uncertainty than estimating the impact

⁴⁶ For a full discussion of uncertainty in emissions, see e.g. Ebert and Karmali (1992).

Box 2: Applications of decision analysis

Option analysis: In conventional CBA analysis, the usual decision rule is to take some action if the expected benefits exceed the expected costs. Depending on the degree of irreversibility present, a more appropriate rule is to take the action when benefits exceed costs by an amount at least equal to the value of the forgone option. Suppose some investment depends upon some assumptions that are subject to great uncertainty – such as future world oil prices. If one makes some investment decision that is largely irreversible – such as building a large hydroelectric power project – then one loses the flexibility associated with waiting to learn more about the factors that affect oil prices. Preserving that flexibility has some economic value, namely the so-called option value. In financial and commodity markets such options to buy (and sell) are traded, with option prices determined by the market itself. But option value theory is now being applied to other fields involving capital intensive investments – such as power generation.¹ In applying these concepts to the climate change problem, there are of course many key differences. First, in one sense the problem is exactly opposite to that faced, say, by the power sector: in climate change, one loses flexibility if one does *not* make short-term investments to reduce GHG emissions. Second, unlike in the financial and commodity context, there is no marketplace to set the value of the option.²

Decision analysis and hedging strategies: Among the foremost exponents of applying decision analysis to the global warming problem are Manne and Richels,³ who have developed an approach for determining the optimal hedging strategy. The paradigm they use is that of a portfolio of insurance options:⁴ what combination of insurance should be bought, if indeed any at all? "...what portion goes to R&D to resolve scientific uncertainties? What portion goes to the development of new supply and conservation technologies to reduce abatement costs? And what portion goes to immediate abatement of emissions? Particularly they focus on the value of information⁵ how much accuracy is needed in climate modeling and impact assessment? Clearly, with perfect information, the best course of action can be charted immediately, and there is no need to hedge bets. Manne and Richels conclude that the need for precautionary near-term emissions reductions is inversely related to the sustained commitment to R&D to develop better climate information (which reduces the need to hedge against an uncertain and potentially hostile future).

¹ See e.g. E. Crousillat and S. Mertzoukos, *Decision-making under uncertainty: An option valuation approach to power planning*, Industry and Energy Department Working Paper, Energy Series Paper 39, World Bank, Washington, DC, 1991. This study reviewed power sector investment decisions in Costa Rica, Hungary and West Africa.

² A marketplace might of course emerge if a tradable emissions permit system were to be instituted. Chao and Wilson (1993) outline a means of using option values to quantify the flexibility associated with the purchase of a tradable emissions permit instead of fixed capital investment in control technology.

³ See e.g. A. S. Manne and R. Richels, *Buying greenhouse insurance: the economic costs of carbon dioxide emission limits*, MIT Press, Cambridge, MA, 1992.

⁴ L. Lave (*Are economists relevant? The efficiency of a carbon tax*, in Dornbusch and Poterba (Eds) *Global Warming: Economic Policy Responses*, MIT Press, Cambridge, MA, 1991) notes that the concern about global climate change is not merely concentrated in the rich nations, but in the upper income groups in those nations; these are the same groups that voluntarily purchase insurance to protect themselves against other losses: health, flood, earthquake. Persuading poor people to buy flood or earthquake insurance is exceptionally difficult even in the developed countries.

⁵ The value of information under uncertain conditions is a concept much used in the private sector. For example, in oil exploration, before drilling a wildcat well – a very expensive proposition – the question arises as to how much ought to be spent in much less expensive prior survey work: general magnetic surveys, or more expensive seismic surveys? Neither yields perfect information. For details of how such decision-theory models are applied in this field, see e.g. Newendorp (1976).

on agriculture, or on biodiversity.

5. **Uncertainty about the assumptions underlying policy options.** For example, a number of studies have estimated the impact on GHG emissions of eliminating subsidies on coal, or on electricity, using assumed values of price elasticity.⁶⁷ General equilibrium models require all kinds of assumptions about the elasticities of substitution, whose actual values used in the numerical simulations are either based on historically estimated elasticities, or upon the judgment of the modeler. In either case there is uncertainty about the extent to which such values match actual behavior.
6. **Uncertainty over the effectiveness of policies.** For example, the proposition that a certain level of carbon tax will in fact result in the hypothesized fuel substitution makes a number of assumptions about the functioning of markets. As noted earlier, the very fact that many apparently "no regret" options are not being implemented suggests a higher level of market imperfection than economists like to admit, and/or substantially higher transaction costs or discount rates.
7. **Uncertainty about joint benefits and costs.** As noted earlier (see Box 1), joint benefits and costs may be a very significant factor in evaluating options for greenhouse gas abatement. However, these joint benefits and costs are also subject to significant uncertainties (and also measurement problems).

The application of valuation techniques is difficult even where the impacts themselves can be quantified with relative confidence. But in the case of global climate change, however, uncertainties in economic valuation techniques may be significantly smaller than the *scientific* uncertainties that surround the impacts of increasing concentrations of greenhouse gases. Advocates of immediate mitigation action to reduce emissions argue that even if the probability of some of the important impacts are unknown, and subject to great uncertainty, they are not zero. Low probability, high impact events are especially complex to model, and may also elicit counter-intuitive public reaction due to extreme risk-averse behavior (e.g. nuclear accident). Further, the process of global warming, once underway, will be irreversible (at least during a period measured in centuries), and the damages which may result are so catastrophic, that action may be warranted even in the absence of more precise scientific knowledge about the impacts.

A good analogy is a nuclear power plant accident. The Chernobyl incident notwithstanding, the risk of catastrophic accident is extremely small. But the cost of a major accident is undoubtedly very large. Both the probabilities⁶⁸, as well as the cost of the impacts, are very difficult to estimate. But even if one could agree on appropriate values to use, and one were able to calculate an expected value, decision-making on the basis of the expected value may still not reflect the preferences either of the public or of decision-makers. The consequences of even an extremely unlikely event may be perceived as so undesirable (especially in the case of extreme risk aversion), that "normal" decision rules may simply not be viewed as appropriate. In other words, cost-benefit analysis must deal not just with expected values, but also with risk preferences of the decision-makers, and those they represent.

⁶⁷ see note 42, *supra*.

⁶⁸ The US Nuclear Regulatory Commission has made repeated attempts to establish probabilities for specific kinds of accidents through a technique known as fault tree analysis. Despite the appearance of scientific rigor, the resultant probability estimates remain highly controversial. For examples of the use of cost-benefit analysis by the US NRC, see e.g. Mubayi *et al.* (1991) or Abrahamson *et al.* (1989).

The traditional and simple way of incorporating uncertainty considerations in CBA has been through sensitivity analysis. Using optimistic and pessimistic values for different variables can indicate which variables will have the most pronounced effects on benefits and costs. While sensitivity analysis need not reflect the probability of occurrence of the upper or lower values, it is useful for determining which variables are most important to the success or failure of a project (Dixon *et al.* 1988). Indeed decision-makers often assign (even if only implicitly) probabilities to the various outcomes. Admittedly, the sheer magnitude of the costs of catastrophic climate change will make the sensitivity analysis problematic.

One might note that for certain types of uncertainty, something akin to risk insurance is available in the form of futures and options markets. For example, one can hedge against uncertainty in the future price of oil by transactions in the oil futures markets, but their efficient functioning depends upon there being some balance between those who are buyers of oil (who are primarily interested in protecting themselves against a rise in the price), and sellers of oil (who are interested in protecting themselves against a fall in the price of oil). (See Box 1)⁹

Finally, extreme uncertainty might also influence the nature of the economic instruments employed for policy purposes. For example, a price-oriented mechanism (such as a carbon tax) which limits economic dislocation might be preferred over a quantity-based mechanism (such as tradable permits) in a situation where there are both uncertain control costs and an uncertain environmental response (see Lave and Gruenspecht, 1991).

Valuation

The robustness of a cost-benefit analysis depends critically on how reliable the values attached to each item are. The prices of marketable goods and services express social values as long as the goods in question are not rationed and there are no externalities. For non-marketable goods and services, such as many environmental services, values have to be estimated in order to aggregate costs and benefits and obtain an overall evaluation of choice of policy. "Synthetic" prices will depend on the methodology chosen to create them, and one should therefore interpret results which include such prices with caution.

One reason why avoiding climate change may have a value is that climate change will cause a change in economic activities. Sea level rise will force people to move, more turbulent weather conditions may increase the need for rebuilding of damaged materials etc. A second reason is that people attach subjective values to the climate where they live, to some extent reflected in the notions of "good" and "bad" weather.

However it is difficult to assess these values. To simplify somewhat, one may base an estimate on the anticipated costs of achieving a certain target at observed market prices, for instance the minimum abatement cost of attaining the same level of greenhouse gases emissions as a previous year. Alternatively, one may estimate the willingness to pay for reaching such a target. In neither of the cases, however, would one be able to assess the equilibrium price, or the value. The choice of approach might therefore be strictly decisive for the conclusion, for instance if pollution that causes severe damage (high willingness to pay) could be avoided by low costs.

Valuation of environmental effects in CBA may be helpful in attaining cost-effective decisions. However, the valuation should be based on a reasonably well founded methodology. Speculative assumptions will not contribute to decision making. A measure which yields negative net benefits according to an analysis may be worthwhile to accept if effects that are

⁹ Precautionary expenditures may also be influenced by aversion to catastrophic risks. A recent example is the hundreds of billions of dollars per year spent in the U.S. to avert soviet nuclear attack.

assumed to be positive but not explicitly valued in the calculation are well documented. Decision makers will normally manage to consider more than one measure simultaneously. CBA usually simplifies the decision by aggregating several effects, but there is no necessity for all effects to be aggregated into one single measure.

There are several fundamentally different types of costs and benefits that must be addressed, each of which requires somewhat different approaches to quantification and valuation:

1. Mitigation actions taken before the actual impacts are observed. These are primarily a matter of emissions reductions, or of removing GHGs through reforestation. The vast majority of the applications of cost-benefit analysis have addressed the question of how best to achieve given levels of emission reduction reductions. Valuation issues generally do not arise in this category.
2. Costs of mitigation actions taken after impacts become apparent. These will necessarily occur in the future, and would be undertaken only if (1) global warming actually does occur, and (2) that global warming does in indeed result in specific impacts. The cost of dikes to prevent inundation of coastal areas is a typical example in this category: based on actual experience (such as in the Netherlands) the cost of such mitigation actions are relatively easy to establish. Climatic engineering options also fall in this category, such as painting roads and roofs white, or putting particles into the stratosphere. Again there are few valuation issues here.
3. Costs (and benefits) of Adaptation. Society will adapt with varying degrees of pain to many of the impacts of global warming. For example, climate change will affect crop yields, and result in Northward shifts in cultivated land. Some areas will gain, and some will lose, which becomes an equity issue (between regions and countries) as much as a cost issue. Estimates of net losses for U.S. agriculture, for example, suggest a tolerable impact for the U.S. as a whole, but significant regional variations.¹⁰ Some of the costs of adaptation will vary, depending on ex-ante actions (e.g. more agricultural R&D expenditure to develop drought or saline resistant crops).
4. Costs (and benefits) of non-adaptation. In some cases, adaptation may not be possible, and/or the cost of mitigation may be higher than the loss incurred in its absence. For example, in some areas, the cost of construction of dykes may be far higher than the value of the land lost to coastal flooding, in which case the relevant cost to be estimated for purposes of CBA is the value of the land lost.

It is thus in the third and fourth of these categories that valuation issues arise. Table 5.1 lists the specific categories of impacts that may be encountered as a result of global climate change, together with an indication of the degree of valuation difficulties likely to be encountered.

Conceptually, the total economic value (TEV) of a resource consists of its use value (UV) and non-use value (NUV).¹¹ Use values may be broken down further into the direct use value (DUV), the indirect use value (IUV) and the option value (OV) (potential use value). One needs to be careful not to double-count both the value of indirect supporting functions and the value of the resulting direct use. One major category of non-use value is existence value (EV). Thus

¹⁰ "Preliminary results suggest that although US crop production could decline, supplies would be adequate to meet domestic needs" (EPA, *op.cit.*, 1989, p.93).

¹¹ For further details, see Munasinghe (1993).

Table 5.1: Potential impacts to be valued¹

Systems	Potential Impacts
forests/ terrestrial vegetation	migration of vegetation reduction in uninhabited range altered ecosystem composition
species diversity	loss of diversity migration of species invasion of new species
coastal wetlands	inundation of wetlands migration of wetlands
aquatic ecosystems	loss of habitat migration to new habitat invasion of new species
coastal resources	inundation of coastal development increased risk of flooding
water resources	changes in supplies changes in drought and floods changes in water quality+hydropower production
agriculture	changes in crop yields shifts in relative productivity and production
human health	shifts in range of infectious disease changes in heat-stress and cold-weather afflictions changes in fertility due to stress
energy	increase in cooling demand decrease in heating demand changes in hydropower output
transportation	fewer disruptions in winter transportation increased risk for summer inland transportation risks to coastal roads
also considered in EPA study	
air quality	
other impacts not considered in OTA or EPA studies	
weather-related damages	damages related to changes in the frequency and severity of extreme weather events like storms
amenity value	
construction	
industry	

¹ Systems and potential impacts as listed in OTA, *op.cit.*, p.15.

$$TEV = UV + NUV$$

or

$$TEV = [DUV + IUV + OV] + [NUV]$$

Figure 5.1 shows this disaggregation of TEV in schematic form. Below each valuation concept, a short description of its meaning and a few typical examples (based on a tropical rainforest) of the environmental resources underlying the perceived value, are provided. Option values and non-use values and existence values are shaded, to caution the analyst concerning some of the ambiguities associated with defining these concepts — as shown in the examples, they can spring from similar or identical resources, while their estimation could be interlinked also. However, these concepts of value are generally quite distinct. Option value is based on how much individuals are willing to pay today for the option of preserving the asset for future (personal) direct and indirect use. Existence value is the perceived value of the environmental asset unrelated either to current or optional use, i.e., simply because it exists.

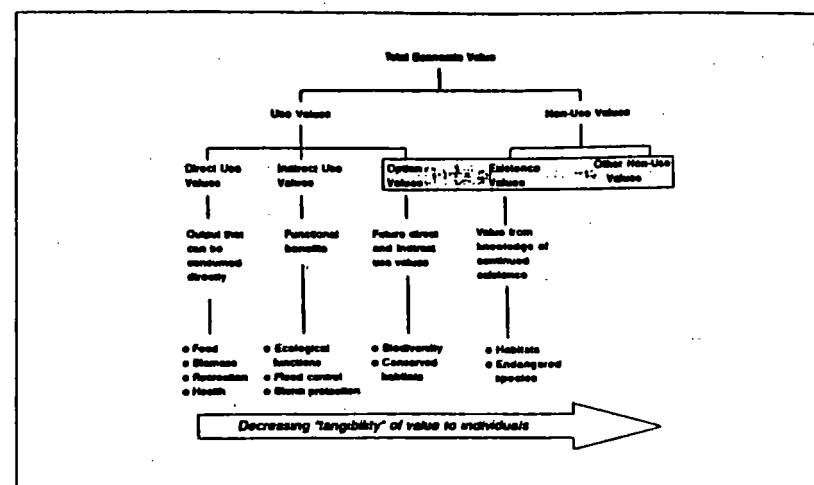


Figure 5.1: Categories of economic values attributed to environmental assets

A variety of valuation techniques may be used to quantify the above concepts of value.³² The basic concept of economic valuation underlying all these techniques is the willingness to pay (WTP) of individuals for an environmental service or resource, i.e., the area under the compensated or Hicksian demand curve. As shown in Table 5.2, valuation methods can be categorized according to which type of market they rely on, and by considering how they make use of actual or potential behavior.

Table 5.2: Taxonomy of relevant valuation techniques

	conventional market	implicit market	constructed market
based on actual behavior	change of productivity loss of earnings defensive or preventative cost	travel cost wage differences property values proxy marketed goods	artificial market
based on potential behavior	replacement cost shadow project		contingent valuation

source: Munasinghe (1993)

We note that these valuation techniques have been developed for more conventional environmental impact analysis, and would require significant modification and/or careful interpretation when applied to global climate change (e.g. long-term intergenerational impacts, biodiversity loss, welfare comparisons across cultures, or where there are wide gaps between gainers and losers, etc.).

³² For a recent overview of techniques suitable for valuing environmental costs and benefits, see M. Munasinghe, *Environmental Economics and Sustainable Development*, World Bank Environment Paper 3, Washington, DC, 1993.

Discount rate

We noted in the introduction that CBA requires a very specific and explicit way of dealing with time. The first principle is that past (or "sunk") costs are ignored, based on the premise that since past decisions cannot be changed, they have no bearing over decisions regarding the efficiency of resource use that are to be made in the present or in the future.⁵³

The second principle is that a discount rate is applied to future costs and benefits to yield their present values. The issue of choosing an appropriate discount rate has been discussed in the context of general CBA for many years (Dasgupta et al. 1972, Harberger 1976, Little and Mirrlees 1974, Sen 1967). The long term perspective required for sustainable development suggests that the discount rate might play a critical role in intertemporal decisions concerning the use of environmental resources (Lind and Arrow 1982).

Compared with most other economic investment decisions, the time perspective of measures aiming at mitigation of climate change is considerably longer. Cline (1992) suggests a 200 - 300 years time horizon for climate policy decisions, while investments in economic activities seldom need more than a 25 years horizon. This makes assumptions about how the economic and the environmental systems will develop, and the discounting of values that occurs in the future critical to the evaluation of measures.

The discount rate denotes the social opportunity cost of capital. It reflects total social benefits if one unit of present output is withdrawn from consumption and rather is invested for instance in production or abatement. The criteria for optimal social and economic development is that the marginal total benefits from the investments should be equal regardless of what the investment is aiming at. In other words, the social discount rate should be equal for all investments. If not, it would be possible to reallocate resources and attain a higher social benefit without any cost. Thus, the discount rate expresses a condition for dynamic (or intertemporal) efficiency.

The discount rate provides a signal to decision makers who evaluate single projects or measures to take decisions in accordance with dynamic efficiency. Although the requirement to apply an equal discount rate for marginal projects is inevitable, there are many potential optimal levels of the discount rate. This level depends, *inter alia*, on the social preferences about present versus future consumption which may be reflected by an intertemporal welfare function. The formulation of this function has been the subject of an extended debate in which questions about intertemporal comparisons as well as current welfare contributors have been raised.

Two concepts mainly help to shape the discount (or interest) rate in a market economy. First, there is the personal rate of time preference of individuals which determines how they compare present-day with future consumption. Second, there is the rate of return on (or opportunity cost of) capital, which determines how an investment (made by foregoing today's consumption) would yield a stream of future consumption (net of capital depreciation or replacement). In an ideally functioning market, the interest rate which equilibrates savings and investment, also equals both the marginal rates of time preference and return on capital. In practice, government policy distortions and market failures lead to divergences between the rates of time preference and return on capital. Furthermore, the social rate of time preference may be less than the individual time preference rate, because long-lasting societies are likely to have a bigger stake in the more distant future than relatively short-lived individuals.

⁵³ One needs to take note of the fact that this principle is also not universally accepted, particularly by political leaders: the principle that "past sacrifices ought not to be in vain" is frequently invoked as relevant to present decisions.

Box 3: Discount rate and inter-temporal choice

In order to illustrate some important intertemporal choices when deciding about the social welfare function, however, it suffices to apply the additive one, which indeed represents the standard choice.

$$W(c(t) \dots c(T)) = \sum_{t=T}^1 U(c(s)) / (1+\delta)$$

$W(c_1 \dots c_T)$ is total utility from t to T , which is the sum of the utilities at each time s from t to T , as evaluated at t . $U(c(s))$ is the utility of consumption at s , evaluated at s . δ is the rate of impatience. For simplicity we do not distinguish between total consumption and consumption per capita in this illustration.

The marginal utility of consumption, which is the quality gain from a given increase in consumption, is assumed to be decreasing. In an intertemporal context, this means that an increasing consumption path yields less utility per unit consumption as time passes. How much, depends on the elasticity of marginal consumption, denoted ω . This expresses the attitude towards the distribution of consumption among generations (formally $\omega = -cU''/U'$, where accents denote partial derivatives). The more weight the society gives to inter-generational equity, the higher the value of ω .

The other intertemporal implication of the choice of a welfare function is the choice of δ . Impatience means that preferences over given consumption levels to be consumed in each future year implies the highest level the first year, the second highest next year and so forth till the lowest level the last year. There is empirical evidence that δ is positive, meaning that people seem to be impatient with respect to their own consumption. However, the climate change issue is a genuine intergenerational problem, and one may ask whether individual impatience ("from me to me") is of relevance in such a context ("from me to my descendants"). It should be emphasized, though, that impatience does not imply decreasing consumption. This is because output withdrawn from consumption can be invested and yield a social return next year, thus making the consumption potential higher. The problem is to balance these respects. Optimal economic development requires the following relation between the social rate of return, denoted $\gamma(t)$, and the rate of consumption growth $\dot{c}/c$ to be fulfilled.

$$\gamma(t) = \delta + \omega \dot{c}/c$$

Assuming that we know the parameters δ and ω , we can assess the social rate of discount if the optimal rate of consumption growth is known, or vice versa. This means that a high discount rate reflects a high rate of growth in consumption. Accordingly, a rapid decline in consumption due to an "environmental disaster" in the far future would, if optimal, result in a low, perhaps negative, discount rate. This would make decision makers take such effects into account, even in present day decisions. Note that in general, there are no reasons why the discount rate should be constant over time even if δ and ω are constants, since $\dot{c}/c$ need not be constant. In fact, if we assume a gloomy scenario where future output and consumption decline, then $\dot{c}$ may be negative and $\gamma(t)$ could decline over time (Munasinghe, 1993, Stierner, 1994).

By observing the variables of the above equation, one will normally find that the left hand side differs from the right hand side. There may be several explanations to this, and there is a broad literature discussing how to assess the "correct" social discount rate (see Lind (1982) for a survey). Applying the return on private investments, for instance, one has to take into account that the observations will be affected by the existing tax system, which normally is not "perfect" in the sense that it reflects all the social consequences of a private investment, such as the consequences of climate change.

The rate of capital productivity is very high in many developing countries, because of capital scarcity, and the rate of time preference also is elevated because of the urgency of satisfying immediate food needs rather than ensuring long term food security (Pearce and Turner 1990). Projects with social costs occurring in the long term and net social benefits occurring in the near term will be favored by higher discount rates. Conversely, projects with benefits accruing in the long run will be less likely to be undertaken under high discount rates. Thus, some environmentalists have argued that discount rates should be lowered to facilitate environmentally sound projects meeting the CBA criteria. However, this would lead to more investment projects of all types, thereby possibly threatening fragile environmental resource bases. Norgaard (1991) argues that lowering discount rates can in fact worsen environmental degradation – by lowering the cost of capital and thereby lowering the cost of production, more is consumed in the near-term relative to the case where discount rates were higher. Further, using a very low discount rate to protect future generations is inequitable, since it would penalize the present generation and increase inequalities across time periods – especially when the present contained widespread poverty (Pearce 1991).

In order to facilitate such intergenerational transfers, one option is to impose a sustainability constraint, whereby current well-being is maximized without reducing the welfare of future generations below that of the current generation. In practice, this would entail monitoring and measurement of capital stocks (man-made, human and natural), and a broad investment policy which sought to ensure that compensating investments offset depreciation of existing assets (Pearce 1991). Theoretically, the aim would be to ensure that the overall stock of assets is preserved or enhanced for future generations, but practical application of this principle would be difficult.

It is worth emphasizing that although externalities related to climate change will affect the social rate of discount, it is not sufficient to merely adjust this discount rate in order to take full account of climate change in a CBA. One must include also the "price" of the environment, which may increase substantially over time. As a consequence, future impacts from climate change may be quite important to present day decisions, even in "discounted terms": A five per cent increase in the price of the environment will fully counteract the effect of a five per cent discount rate.

To conclude, discounting is necessary to attain a socially optimal development. Attempts to avoid discounting or to apply a different discount rate for climate measures than other investments will inevitably result in an inefficient policy. However, it is difficult to pick out the correct level of the optimal social rate, as there are no observations of such a rate. Furthermore, discount rates may depend on the future scenario that is assumed, and could vary over time – in particular very long term discount rates may be lower as growth rates saturate (see Box 3).

CBA and Equity

CBA can provide answers on who should engage in how much abatement based solely on the criterion of maximizing economic efficiency. It must however be recognized that some deviation from the global least-cost solution as obtained by CBA may have to be accepted in order to get international agreement. As indicated earlier on Figure 2.1, there will likely be a trade-off between equity objectives and economic efficiency.³⁴ CBA can help define the trade-off curve, but it cannot provide an answer to what combination of economic efficiency and equity is necessary to get international agreement. However, whether there is a trade-off between equity and efficiency (and the properties of this trade-off) depend upon what policy

³⁴ Equity Issues are dealt with in detail by Writing Team 4

instruments are available. For example, if one permits side-payments (of some kind) between countries, the efficient allocation of emissions across countries is independent of the equity issue.

Several concerns shape equity perceptions and the ability to obtain international agreements. Effective action to control global warming is dependent on a degree of international agreement. Therefore a first obstacle to whatever mechanism might be agreed upon is national sovereignty – to what extent will sovereign nations subject themselves to enforcement actions by others? Even simple agreements for joint implementation of projects involving two countries have run into difficulties (see below).

The second obstacle is the heterogeneous nature of the effects of greenhouse warming. Although the most widely cited measure of global warming is the average increase in global temperature, global warming affects different countries differently. In addition, the costs or response measures and their economic implications vary greatly among countries, particularly as a function of the level of development. Therefore the perceptions of benefits of global cooperation will differ greatly.

A third obstacle is posed by strategic incentives. If some countries take the lead and set up a greenhouse gas agreement, others have an incentive to free-ride and abstain from joining, as they cannot be excluded from the benefits such an agreement creates. If countries act selfishly in this way, few will become party to an agreement. Most countries will therefore not cooperate and no general agreement will be reached even if all countries were to benefit from it. (This is the well known prisoner's dilemma from game theory).³⁵ Some argue that the overwhelming historical contribution to the build-up of GHGs from developed countries constitutes an "environmental debt", that cannot be conveniently ignored using the traditional "sunk cost" approach. If past contributions to GHG emissions are considered from an equity viewpoint, establishment of appropriate side-payment mechanisms from developed to developing countries, including financial assistance and technology transfer, could facilitate the more enthusiastic cooperation of developing countries in global warming mitigation efforts.

The question of joint implementation illustrates the limits of CBA in this regard. The motivation for joint implementation is a straight forward result of CBA. If a country – say the U.S. – decides to make an effort to reduce GHG emissions, and if reductions can be obtained at lower costs abroad, then the US should initiate projects in other countries in order to minimize overall costs (Aaheim, 1993). The receiving country has nothing to lose if the additional cost of such a joint implementation project is covered by the investing nation. Yet many countries and organizations have reacted with skepticism, for reasons that are political, and based on equity concerns, rather than on economic efficiency. The reasons include the mistrust of the true willingness of the industrial countries to mitigate climate change; the belief that the ultimate reduction in GHGs under such a regime would be negligible; and the suspicion that joint implementation gives industrial countries an opportunity to "buy themselves out of their problems" at the expense of the developing countries.³⁶ Indeed, some developing countries fear that joint implementation investment might partly substitute for traditional forms of financial and donor assistance, and that such agreements might preclude the right of future generations to emit GHGs.

³⁵ However, for a criticism of this argument, see e.g. Brown (1992), who points out that some European countries have already taken unilateral action to reduce greenhouse gases, in hopes that others will follow.

³⁶ For a discussion of these issues, and a discussion of how CBA can make a contribution to the evaluation of such projects, see Aaheim (1993). Concerns about "market justice" and related considerations are outlined in Rose (1990).

Multicriteria analysis

Even the staunchest advocates of cost-benefit analysis would concede that economic efficiency (or economic value) is not the sole criterion in setting public policy, and that policy-makers rightfully need to consider a broader set of objectives. Unfortunately there is much confusion about what constitutes a coherent set of objectives. Table 5.3, taken from a major EPA study, lists the criteria suggested there as constituting the basis for selecting public policy. Economic efficiency is one of fifteen so listed.

Simple applications of CBA tend to focus only on economic efficiency. However, in more recent extensions, traditional CBA concepts are embedded in MCA, that expressly allows more than one objective, and expressly addresses risk and uncertainty – thereby providing an integrating mechanism for most of the criteria listed. Multicriteria analysis techniques first gained prominence in the 1970s, when the intangible environmental externalities lying outside conventional cost-benefit analysis (CBA) methodologies were increasingly recognized. It also met one objective of modern decisionmakers, who preferred to be presented with a range of feasible alternatives – as opposed to one "best" solution. MCA also allows for the appraisal of alternatives with differing objectives and varied costs and benefits, which are often assessed in differing units of measurement.

Table 5.3: Criteria for choosing a strategy

1. Flexibility
2. Urgency
3. Low cost
4. Irreversibility
5. Consistency
6. Economic Efficiency
7. Profitability
8. Political feasibility
9. Health and Safety
10. Legal and administrative feasibility
11. Equity
12. Environmental quality
13. Private v. Public sector
14. Unique or critical resources

Source: EPA, *The Potential effects of global climate change on the United States*, EPA-230-05-89-050, Washington, DC, December 1989, p.390.

Thus, upon closer examination of the criteria listed on Table 5.3, criteria 1, 2, 3, 4, 5, 6 can all be treated by modern decision-analysis: indeed, questions of timing (urgency), flexibility (or robustness), capital constraints ("low cost") are all central elements of the approach. Criterion 13 is really part of 6 (in the text the authors of the EPA report amplify the criterion as follows: "Does the strategy minimize governmental interference with decisions best made by the private sector" ?). Furthermore, modern valuation techniques permit substantial parts of Criteria 9 and 12 to be included in the economic analysis as well. As conceded by the EPA report (p.393), "if the principal costs and benefits can be quantified in monetary terms, economic theory provides a rigorous procedure for making trade-offs between present and future costs, and for considering uncertainty, profitability, and most of the other criteria".

There is also a need to separate the basic goals of public policy – such as economic efficiency and equity – which surely have primacy, from implementation issues such as legal and administrative feasibility, which are generally secondary. The premise of CBA analysis is

that one looks first at the primary objectives, and then asks how much of the primary objectives one may have to sacrifice to achieve practical implementation. This principle has become accepted in many areas of policy-making. For example, the starting point for setting electric utility rates is to calculate the economically efficient tariff (based on marginal costs), and then make adjustments to protect low income groups (through lifeline rates, special provisions for disconnection in the event of non-payment, etc.). The essence of the approach is not that non-economic issues are ignored, but that the trade-offs between economic efficiency and equity (or indeed other objectives not readily monetized) are explicitly quantified and displayed in such a manner that decision-makers are made aware of how much of one objective is traded off in the interests of the other.

The application of MCA methods involves the following steps:

1. Selection and definition of attributes, say A_i , $i=1, \dots, N$, selected to reflect important planning objectives. While the two major relevant attributes in the context of the global climate change problem are cost and GHG emission reductions, we have already noted that strategies to control GHG emissions may have other side-effects, some positive, and some negative, which may also difficult to value, and which might therefore require additional attributes (such as, for example, for biodiversity)
2. Quantification of the levels A_{ij} of the i attributes estimated for each of the j alternatives. In this quantification, full consideration must be given discounting issues, for non-economic and economic attributes alike. At this stage of the analysis, trade-off curves are powerful tools to communicate with decision-makers: they are particularly relevant in a situation, such as the climate change problem, where the quantification of benefits may be difficult, and where decision-makers must act largely on the basis of trading-off short-term costs against certain levels of GHG emission reduction.
3. Determination and application of a decision rule, which amalgamates the information into a single overall value or ranking of the available options, or which reduces the number of options for further consideration to a smaller number of candidate plans. Where amalgamation is contemplated, attribute levels are first translated into a measure of value, $v(A_{ij})$ (also known as the attribute value function).¹⁹ This is sometimes combined with a normalization procedure usually on a scale of zero to one (in which the lowest value of the attribute value function is assigned zero, the highest one). Subsequently weights w_i for each attribute must be determined to arrive at the overall amalgamation.

Trade-off curves are a particularly useful tool for analysis of energy-environmental policy options. Figure 5.2, taken from a recent study of options for greenhouse gas (GHG) emission reductions in Sri Lanka (Meier, Munasinghe and Siyambalapitiya, 1993), illustrates the essential concepts. The figure is a plot of two attributes – GHG emissions and total system costs – for the technology options identified on Table 5.4. Each point represents a perturbation of the reference case, defined as the official 1993 basecase capacity expansion plan of the CEB.

The *trade-off curve* is the set of options that are not dominated by others (sometimes referred to as the "non-inferior set"). These are the options that are "closest" to the origin, and therefore represent the "best" set of options that merit further attention.²⁰

Several useful concepts arise here. First is the concept of *dominance*.²¹ PFBC (a clean coal technology) is said to dominate the options in the sector shown, namely FGD, wind and

¹⁹ MCA deals with attitudes toward risk and uncertainty at this stage by the use of multi-attribute utility functions, which explicitly capture attitudes toward risk (see Keeney and Raiffa, 1976; Keeney and Wood (1977) for an application in water resource planning; or Keeney and von Winterfeldt (1987) for application to electric utility planning).

²⁰ We note also that the trade-off analysis and surfaces will be much more complex as the number of attributes increases.

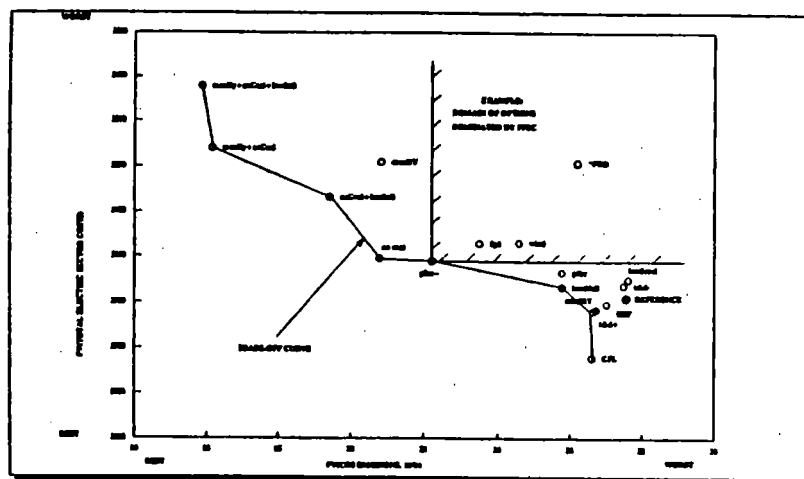


Figure 5.2: Trade-off curve

source: Meier, Munasinghe and Siyambalapitiya (1993)

*FGD. PFBC has better costs and better (lower) GHG emissions, and is thus preferred over these options under both criteria. If only these two attributes mattered, then there would be no reason to select any of the dominated options in place of PFBC.

Another perspective is gained by dividing the solution space into quadrants with respect to the reference case (Figure 5.3). The options that fall into quadrant III are the "win-win" options, which are better than the reference case in *both* attributes. In this case, mini-hydro, energy efficient refrigerators, T&D system loss reduction and compact fluorescents all fall into this quadrant, providing both cost and emission gains. Such win-win solutions were mentioned earlier, in Section 4, in connection with the empirical estimates of the MAC curves (e.g. Figure 4.2): these "below-the-line" options in the MAC curves are equivalent to the options in quadrant III of a multi-attribute analysis.⁶⁰

⁶⁰ Decision analysis distinguishes among several types of dominance – such as strict dominance and significant dominance – see e.g. Meier and Munasinghe (1994) for an application of these concepts to environmental decision-making.

⁶¹ In general, of course, the trade-off curve may extend into quadrant II; and quadrant III may contain fewer, or need not contain any solutions at all.

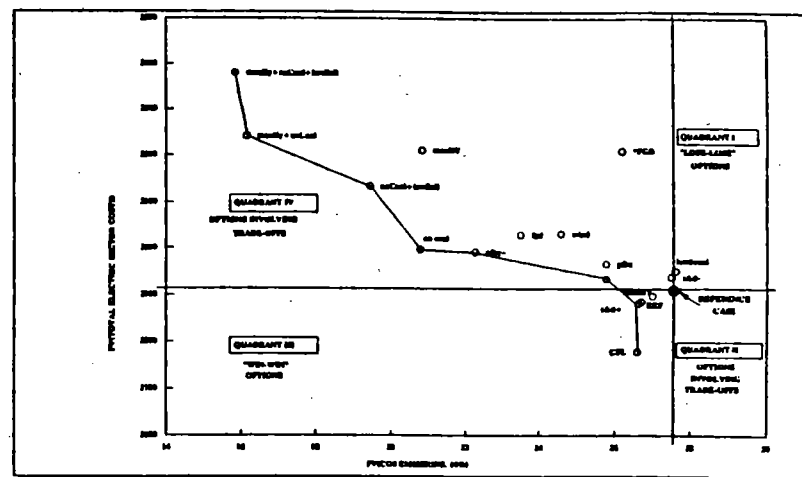


Figure 5.3: "Win-win" options

source: Meier, Munasinghe and Siyambalapitiya (1993)

Table 5.4: Technology interventions for GHG emission reductions

option	comments	symbol
wind energy	305 Mw total	wind
mini-hydro		minihy
DSM: energy efficient refrigerators		EEF
DSM: compact fluorescents		CFL
T&D loss reduction	10% T&D loss goal (in place of 12%) by 2000. 12% goal delayed to 2003	TD+
max hydro	builds both reservoirs in the Upper Kotmale project, 144Mw high dam version of Kukule.	maxHy
clean coal technology	pressurized fluidized bed combustion-combined cycle units, assumed for all coal units after 2000:	PFBC
	with pessimistic capital cost assumptions	PFBC-
clean fuels	use imported low-sulfur residual oil for diesels (0.5% S by weight rather than 2.5% S).	low S oil
	use low sulfur (0.5%) coal (rather than 1% S coal)	low S coal
FGD systems	model free to choose optimal generation mix; coal plants must have FGD systems.	FGD
	FGD systems forced onto basecase solution	**FGD
no coal	model free to choose least-cost combination of diesels +hydro	noCoal

Concluding Remarks

Cost-benefit analysis has many advocates but also many detractors. Certainly the rather narrowly defined, traditional approaches to CBA, developed originally for project level decision-making with planning horizons typically no more than 20 years, clearly are dealing with the very long time frames, non-marginal impacts, and high levels of uncertainty, encountered in the appropriate context of climate change.

In the introduction we noted that there were four essential questions facing decision-makers regarding climate change: (1) by how much should emissions of GHGs be reduced?; (2) when should emissions be reduced?; (3) by what methods should emissions be reduced?; and (4) who should reduce emissions?

The first question is answerable in principle, using CBA — the measures whose marginal costs are less than the marginal damage costs should be implemented. Clearly, it matters what perspective is taken, since the result will be different if restricted to a consideration of national costs and benefits than if the perspective is global. It is a fundamental result of CBA that the global perspective is the proper one, in the sense that it maximizes net benefits worldwide. The national perspective is relevant when equity issues related to the incidence of costs and benefits are considered (see question 4 below).

The second question is a more complicated one, because it involves judgments about uncertainty. If the marginal damage (benefit) cost were known with certainty, or if future technological advances that might significantly change the marginal cost curve were known with certainty, then the timing of abatement is given by that portfolio of implementation options that maximizes the (deterministic) present value of avoided damage costs (benefits) less abatement costs — a relatively straight forward calculation. But since neither damages nor costs are known with certainty (for example, if fusion technology were to be commercially available at a cost comparable to fossil-fueled technology by 2020 then the optimal timing and structure of abatement actions looks very different than if the date were 2070), extensions of CBA — such as decision analysis — are required. As indicated in Section 4 (see e.g. Box 2), recent developments have begun to deal with the question of timing, particularly with respect to the balance between R&D (on both the cost and benefit side) vis-a-vis immediate commitments to emission abatements.

The third question is closely related to the first. As we have seen (for example in Figure 4.2), most attempts to answer question 1 necessarily require consideration of the specific methods that might be used to reduce emissions. A bottom-up, empirical estimation of the marginal cost curve involves analysis of the broad spectrum of possible abatement options, from which marginal cost curves can be derived. Top-down models, typically using national or regional general equilibrium models (recall the results of Figure 4.4), also necessarily require explicit consideration of specific policy or technology options.

CBA cannot itself resolve the fourth question — which involves equity — but it does provide a framework for understanding the trade-offs to be made between equity and economic efficiency. CBA, when applied globally, can identify in which countries abatement costs are lowest, since the global perspective identifies all measures whose marginal costs are less than the global marginal benefits (recall Figures 4.5 and 4.6). But how such a program can be implemented in practice involves putting in place appropriate transfer payment mechanisms, the amount and structure of which is a matter of equity.

Nevertheless, despite its many imperfections, CBA remains the best guide to policy-making for dealing with the essential questions that must be faced in dealing with climate change. CBA forces decision makers to compare the consequences of alternative actions, including that of no action, on a quantitative rather than intuitive or rhetorical basis — and

can certainly make a contribution to resolution of the first three of these questions. And where impacts on non-monetary objectives (social and environmental) must also be considered, extensions of the traditional CBA approach, such as multi-criteria analysis, permit quantitative expression of the trade-offs to be made. At the same time, issues of risk, uncertainty and discount rate may be addressed through an expanded CBA/decision analysis framework that incorporates recent advances in dealing with such difficulties.

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D R A F T 1.1

**Intergovernmental Panel on Climate Change
Working Group III**

Equity and Social Considerations

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DRAFT 1.1

**Intergovernmental Panel on Climate Change
Working Group III**

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DRAFT 1.1

**Intergovernmental Panel on Climate Change
Working Group III**

Equity and Social Considerations

Lead Authors:

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Michael Grubb, and Harold K. Jacobson**

I Introduction

The first principle in Article 3 of the Framework Convention on Climate Change states:

"1. 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."

Because of its inclusion in this principle equity must be a key consideration in all actions taken under the Convention. In common language equity means "the quality of being fair or impartial," or "something that is fair and just." (Flexner, 1987, pp. 656-657)

Science cannot prescribe or decide what would be equitable actions under the Climate Convention. This is the task of the Parties to the Convention. Science can, however, illuminate the meaning of equity and clarify the choices that the Parties face. This is the task of this chapter. It considers concepts of equity, viewing broad concepts within the context of the Framework Convention and the several ways in which this text gives meaning to equity. It then analyses three specific aspects of equity: equity among generations; equity among regions and countries; and equity within countries. Social considerations enter into the discussions of equity in all of the sections.

1.1 Concepts of Equity

Since Plato and Aristotle, theorists who have dealt with economic, political, and social issues have developed and explored concepts of equity. Several broad points emerge from this extensive literature. The first is that equity applies to two separate categories of issues. It applies to both procedural issues—how decisions are made—and substantive issues—the outcomes of decisions.

Procedural equity mandates that similar cases and similarly situated claimants should be treated in a similar fashion. For exceptions to this principle to be regarded as equitable, they must be made on a principled basis. The principle suggests that law should govern decisions, and it provides guidance in how law should be applied. Laws are formulated abstractly, but are applied in specific circumstances. All of the circumstances in which a law would be applied can never be foreseen at the time of the formulation of the law. Starting with Aristotle, theorists have argued that equity demands that law be applied in terms of the intentions of those who established the law, the application should aim at achieving what the legislators would have intended in the specific circumstances or at achieving what would be required by "absolute justice." (Shapiro, 1990, p. 220) Absolute justice refers to a broadly accepted higher notion of what is just. It is in this way that in the Anglo-American common law tradition equity is often introduced into judicial decisions.

Substantive equity has to do with the outcome of decisions, it has to do with the distribution of burdens and the allocation of benefits. There are several broad traditions defining the meaning of equity in this sense. (Young, 1994) They may be summarized in the following categories: parity, proportionality, priority, classical utilitarianism, and Rawlsian distributive justice.

Parity is a formula for equal distribution of burdens or benefits. Parity demands that all claimants be treated equally. *Proportionality* is an Aristotelian principle. Under it burdens or benefits should be distributed in terms of the contributions of claimants. *Priority* argues that those with the greatest need should be advantaged. *Classic utilitarianism* proposes that burdens and benefits should be distributed so as to achieve the greatest good for the greatest number. This Benthanite formula can be expressed mathematically in terms of Pareto optimality. Rawls (1971) carried the concept of utilitarianism a step further, arguing for an equal distribution unless an unequal distribution operates to the benefit of all. *Rawlsian distributive justice* therefore requires that deviations from equality result in overall benefit.

No society has ever regarded any one of these formulae as an adequate criterion for defining substantive equity. None of them have seemed appropriate or practicable as a single standard. Among other reasons, they are not practicable because cases and individuals are rarely identical and burdens and benefits may not be divisible, or if they

are they may not be divisible into shares that are susceptible to precise, cardinal measurement so that it is impossible to apply the formulae directly. In practice, when societies try to achieve equity, they do so in nuanced and subtle ways, applying several criteria and seeking to achieve a balance among them. Nevertheless, the formulae are useful for heuristic purposes. Illustrating the likely consequences of their application can clarify the choices that have to be made in seeking equity in concrete situations such as in the implementation of the Framework Convention on Climate Change. The exploration of the application of these formulae in the following sections of this chapter is for this purpose.

1.2 The Context that the Framework Convention Establishes

The Framework Convention on Climate Change provides guidance as to the relative weight that the signatories would assign to these several formulae. Several other articles, paragraphs, sentences, and phrases of the treaty have implications for the concept of equity as it is used in the treaty's first principle, and they provide a context for the choices that must be made in efforts to achieve the objectives of the treaty. This context should be seen in its entirety before addressing particular issues of equity that will arise. Logic and international law require that particular sections of treaties be interpreted in light of the whole treaty and more broadly in light of general principles of international law not in isolation. (Brierly, 1963) The first principle it should be recalled mentions the concept of intergenerational equity. Many sections of the treaty deal with equity among regions and countries

Beyond the prominent statement in Article 3, paragraph 1, equity is also explicitly mentioned in two other paragraphs of the Framework Convention on Climate Change. Under Article 4, paragraph 2 (a) the developed country Parties¹ to the treaty commit themselves to:

"... adopt national policies and take corresponding measures on the mitigation of climate change. . . . These policies and measures will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objective of the Convention, . . . taking into account the differences in these Parties' starting points and approaches, economic structures, available technologies and other individual circumstances, as well as the need for equitable and appropriate contributions by each of these Parties to the global effort regarding that objective."

This paragraph indicates the Parties intention that equity should be applied not only between developed and developing countries, but among developed countries as well.

The concept of equity also appears in Article 11, paragraph 2. This article relates to the financial mechanism established under the Convention. The paragraph says that:

"The financial mechanism shall have an equitable and balanced representation of all Parties within a transparent system of governance."

The article seeks to insure equitable procedures and outcomes by mandating rules for the composition of the financial mechanism.

Several other sections of the Framework Convention, though they do not specifically mention equity, are relevant to ways in which equity should be interpreted. The broad statement of the Convention's objective in Article 2 states the goal of stabilizing greenhouse gas concentrations at a level "that would prevent dangerous interference with the climate system." It then goes on to specify a time-frame within which this objective should be achieved.

"Such a level should be achieved 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."

This stricture bounds the way in which equity should be achieved.

Paragraph 4 of Article 3 proclaims that all Parties "have a right to, and should promote sustainable development." It goes on to say that measures to protect the climate system should be appropriate to each Party's specific conditions. Paragraph 5 of the same article states that the Parties should "cooperate to promote a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties. . . ." In other words, equity is to be achieved in ways that allow all Parties continued economic growth and international trade is to be an essential instrument in this growth. Strategies are to be tailored to the specific conditions of Parties.

The Framework Convention differentiates between developed and developing country Parties. The preamble notes that developed countries have been and are responsible for the largest share of greenhouse gas emissions, and that the share of greenhouse gas emissions from developing countries will grow. As mentioned above, developed country Parties are required to take immediate action to limit greenhouse gas emissions.

The Framework Convention also singles out categories of Parties for special consideration, thus broadly defining how the concept of equity should be applied. Even though they have the obligations of developed Parties, countries undergoing the transition to market economies are allowed some flexibility. (Article 4, Paragraph 6)

Paragraph 2 of Article 3 states:

"The specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change, and of those Parties, especially developing country Parties, that would have to bear a disproportionate or abnormal burden under the Convention, should be given full consideration."

A preambular paragraph notes the particular vulnerability of: small island and low-lying countries; countries with low-lying coastal areas; countries with arid and semi-arid areas; those that are liable to floods, drought and desertification; and those that have fragile mountainous ecosystems. Another preambular paragraph acknowledges the special difficulties that will be faced by developing countries that have economies that are particularly dependent on the production, use, and exportation of fossil fuels as a consequence of limiting greenhouse gas emissions.

The Framework Convention creates obligations and mechanisms for the transfer of financial resources and technology from developed country Parties to developing country Parties to assist them deal with the adverse effects of climate change and in the implementation of measures to mitigate climate change. All of the categories listed in the preceding paragraph and others that are especially vulnerable are singled out as meriting special consideration in the transfer of resources.

As is readily apparent, the Framework Convention on Climate Change has already provided a substantial context for the interpretation of equity in designing measures to attain the Convention's objectives.

II Intergenerational Equity

(First draft. References not included, language not corrected, August 7, 1994 Karl-Goran Maler)

II.1 Equity and the bearing of risk

I Background

Future climate change may have substantial impacts on the distribution of welfare between different generations. If policies are implemented to reduce the risk of global warming, the burden of abating emissions of greenhouse gases will probably fall more heavily on present generations while the benefits from not having to adjust to climate changes will be incurred by future generations. On the other hand, if climate policies are not implemented, the future generations will bear the burden while the present generations will benefit greatly from continued use of fossil fuels. How should one view this intertemporal distribution of welfare and how should one formulate operational guidelines that would support a more equitable intertemporal allocation of welfare? These are the basic issues in this paper and they are analyzed in the framework of established economic theory.

A discussion of the ethical aspects of climate change would require at least the following steps:

- operationalisation of the theory
- measurements
- ethical values
- conceptual theory of ethics
- policy recommendations

In this paper, I will try to give a sketch of the first item, discuss the operationalisations and in particular for intertemporal equity, and give some hints on the theory of measurements. I will conclude with some aspects on policy recommendations.

II. Ethical theories

What I am going to discuss under the heading of ethical theories is almost completely based on professor Partha Dasgupta's recent book *An Inquiry into Well-Being and Destitution* (1993). This book gives an excellent original and novel presentation of how economic theories can be used to improve our understanding of basic ethical conflicts and their resolutions. There are basically two types of ethical theories we will consider:

- consequentialism
- deontological

Consequentialism theories look at the consequences from actions and the policies that govern the actions. They are therefore goal-based. Thus, a consequentialist theorist would look at the set of possible states, evaluate these states in terms of their consequences and then recommend that state that is most desirable in terms of its consequences.

One particular set of consequentialism theories we will adopt and discuss in the sequel is the set of utilitarian theories. Here the consequences are described in terms of utilities, which simply is another word for well-being of the relevant individuals. The best known utilitarian theory is the classical theory, going back to Bentham, saying that it is the sum or the weighted sum of utilities over individuals that should matter. This is also the basic theory behind much of established welfare economics. However, there are other utilitarian theories. For example, one such could be the maxi-min theory, that is that society should maximize the utility for the individual with the lowest or minimal utility. In connection with global warming, this ethical theory should give highest priority to the poorest country, and in fact give that country sole right to make decisions! There are also many other utilitarian theories. However, for the present discussion, we will keep to the weighted utility sum as the typical theory. Most other theories can be approximated by this by choosing the weights appropriately.

The deontological theories, on the other hand focus more on the process by which decisions are made and less on the consequences from these decisions. Thus, deontological theories judge action by their rightness or wrongness and not solely on their consequences. In fact, one important strand of deontological theories are those founded on procedural fairness. Here procedural fairness is judged independently of the consequences of the action.

One particular important class of deontological theories deal with rights. Nozick, for example, declares that all individuals have a sphere of moral rights in which no one, including the state, is allowed to interfere irrespective of the consequences for well-being from such an interference. Another example of a rights based theory is Rawls'. His first principle of justice declares that *Each person is to have an equal right to the most extensive system of equal political liberties compatible with a similar system of liberty for all*, and this second principle states that *Social and economic inequalities are to be arranged so that they are a) to greatest benefit of the least advantaged*.

Implicit in these statements is the notion of primary goods, i.e. those goods or commodities to which individuals have a right. Among them are various liberties, but it could also be argued that basic needs should also be included. This concept was introduced by several individuals in the 1970's, among them professor Graciella Chichilnisky. It corresponds to the idea that individuals have the right to goods and services necessary to sustain their lives at some minimum standard of well-being making it

worth living. It includes potable water, shelter, minimum nutrition, health care and general environmental resources. If there are infringements of these rights, then we should be entitled to claim that a severe injustice is being committed. From the point of view of climate change, the idea of basic needs is worth pursuing. It is very easy to think of scenarios in which flooding or decreased agricultural productivity will bring about such infringements and should therefore not be tolerated. Thus if we accept this approach some rather strict conclusions about climate change policies can be derived. However, I do believe, probably because of the prejudices I have been accustomed to by my training as an economist, that these ideas can be included in a strict utilitarian framework. For example, if we define utility to include basic needs, we would be able to carry out an intelligent discussion, that can be made operational in terms of a utilitarian framework. I will therefore in the sequel use such a framework.

However, before trying to exploit such a framework, let me remind you of one important consequence of a framework based on rights. If all individuals are going to have rights - such as defined by Nozick or Rawls - to their own life, decisions on the climate must be anchored in their own evaluation and their own judgment of their lives. However, climate is what economists call a pure public good. It will affect anyone but in general differently, and there is no way one can get around a change in the climate. The global climate, as it will affect everyone living on this earth, now or in the future, is a truly global public good. Therefore, it is imperative that we can come up with decision mechanisms by which those who are affected also have something to say. We need new international institutions, i.e. new rules of the game, in order to protect the rights of everyone.

III. Climate change impacts

What are the distributive impacts from climate change and policies for controlling the climate? Basically, we can identify two different categories of impacts:

- Burden of abatement of green-house gas emissions
- Burden from adjusting to changes in climate

Obviously, these two categories of impact will differ in importance between different nations, between different individuals in the same nation, between individuals living in different time epochs. It seems that a policy like business as usual will not impose high burdens on countries emitting much green-house gases while it will impose possibly high expected costs on countries affected adversely from climate change and expected benefits to countries affected beneficially from climate change. The use of the term expected costs and expected benefits here is crucial. In spite of the deep science used and the highly sophisticated computer models climatologists have constructed, they have not so far been able and because of inherent non-linear dynamics will never be able to come up with predictions that are certain. We must recognize as a fact that we have to make decisions

under uncertainty but that the decisions should be as rational as possible. This means that we need to use a stochastic framework to discuss intelligently the distributive impacts of climate policies. But as soon as we have admitted this, we have to recognize another cost item - the cost of bearing the risk. Thus we could argue that climate change impacts usefully could be categorized into the following four groups:

- The intertemporal distribution of expected utility
- The international distribution of expected utility
- The interpersonal distribution of expected utility within countries
- The distribution of the cost of risk bearing

It should be noted that most of the discussion on the economics of climate change has focused on the first three types of impacts but very little if any has been said on the last - the distribution and the size of the cost of risk bearing. The uncertainty aspect combined with irreversibilities - both in abatement and in impacts from climate change - makes the analysis technically difficult but not impossible. Unfortunately, too little has been done in this area.

Furthermore, the combination of the idea of basic needs and risk-bearing has also some far reaching implications. If we accept that individuals have the right to some basic goods - food, shelter, access to environmental resources - and if action like the emissions of carbon oxides threaten the availability of these basic goods, then those who decided on these action must be prepared to compensate those who have lost their fundamental rights to basic goods. An international climate agreement should therefore resolve this issue of risk bearing.

I will in the rest of this presentation focus on the first item - the intertemporal justice. I have made this choice not because I believe this is the most important of the issues but because that is the item for which I can claim some expertise.

IV. Utility

In order to discuss sensibly a utilitarian framework, we need some measure of well-being or welfare. Here we will follow standard economic theory by postulating the existence of a utility function. Let us imagine a list of all factors that are relevant for determining the well-being of an individual. Such a list would include among other things the amount of goods and services that the individual can use for consumption, different aspects of his physical and spiritual environment and his rights and liberties. In view of our interest in climate change, it seems appropriate for this discussion to limit the list to the goods and services available and to those aspects of the physical environment that are determined by the climate. The other variables affecting well-being may be more important but will hardly change because of climate change or by abating the emissions of green-

house gases, and we can therefore exclude them from our study. Thus we are left with a list of factors that for each time period determines the well-being of the individual. In order to measure well-being, we assume that it is possible to aggregate all these factors into one single variable - utility. Utility is therefore a function of the variables determining well-being and is an indicator of well-being.

We will not go into a discussion of the logical and philosophical basis for such a utility function, the reader is referred to (???). Usually, we will assume that the utility function is defined with respect to a time period - a year, the average length of a generation, etc. For each individual there are therefore different sequences of utilities over time, dependent on policies affecting the emissions of green house gases. This holds true, irrespective of whether the individual is living now or belongs to a future generation. What the idea of a utility function has accomplished is for each individual to aggregate a rather long list of factors affecting well-being into one single measure. There remains the much more difficult task of aggregating these utilities over different individuals. In a sense, this is the real ethical problem in connection with climate change.

Professor Kenneth Arrow addressed this issue in 1951 (Arrow 1951) by asking the fundamental question whether individual preferences - irrespective of what they look - can be aggregated in a reasonable way into a social preference relation. His answer is negative. It is in general impossible to aggregate individual preferences to a social welfare function if we require that the aggregation should satisfy some very natural and reasonable conditions, including that no individual should be allowed to be a dictator. Thus, there is in general not possible to deduct "objectively" the social preferences over distribution of well-being from individual preferences. However, professor Arrow proved his possibility theorem for the case when individual preferences could be completely arbitrary. If it is known that individual preferences are restricted to certain types, then it may still be possible to aggregate individual preferences in a consistent and reasonable way to a social ordering (see Sen 1987). We will argue here that when it comes to the distribution of welfare over time, it could be argued that there is a consensus on what should be denoted an equitable distribution of welfare. This is so because of the apparent agreement on the concept of sustainable development.

The idea of sustainable development was introduced by the World Conservation Strategy (IUCN 1980) but became popular only after The World Commission on Environment and Development - the Brundtland Commission - published its report *Our Common Future* 1987. In that report sustainable development was not rigorously defined, but a number of ingredients in sustainable development were identified (not necessarily consistent with each other). It seems that the main idea in the Brundtland report was that the present generation should not make such changes in the present resource availability so as to reduce future generations possibilities to achieve a comparable well-being. This is, obviously, an ethical norm which, if accepted by most decision-makers, may have far

reaching consequences for how we view intertemporal justice. The main purpose of the rest of this paper is to deduce then consequences.

It should be stressed that we are looking at and will be comparing different utility and not climate consequences as such. What we are interested in is the well-being of the and future generations and this well-being is, as we have already discussed, determined by a multitude of many different factors. Climate factors and costs of abating emissions of greenhouse gases are only a few of these factors. It is fundamentally wrong to limit any discussion of intertemporal justice to climate change, or even to all environmental variables. We need a much broader perspective! On the other hand, it will be seen that environmental and in particular climate variables may have a profound effect on discounting.

II.2 Risk and Uncertainty

V. Risk and climate change

The future climate is far from certain. The IPCC predicts that the average temperature will rise with between x' and y' per decade under the emission scenario called business as usual. Although, the expected temperature rise is high, the uncertainty about the future average temperature is also high. However, the future average global temperature means almost nothing as it is local effects that really matter. Unfortunately, the predictions on regional temperature are enormously uncertain and vary substantially the predictions of different climate models. It may even be that in some areas the temperature will go down while it will go up in most others but that we are not able to predict with any greater precision which areas that will experience temperature rise and which will experience cooling. Furthermore, the impact from climate change will surely be affected in a major way by the effects on precipitation and on winds. The climate models predict in general that precipitation will go down in the interior of continents while it will increase elsewhere. However, the precise effects are not known. The sea level is predicted to rise but the amount of rise is of course a rather uncertain factor, partly because of the uncertainty in the predictions of average global temperature and partly because of uncertainty about the dynamics of heat transfers in the oceans.

Thus any prediction of the future climate on any scale is subject to great uncertainty. This uncertainty is partly due to our limited scientific theoretical and empirical understanding of the dynamics of the earth's climate system, but also partly because the climate is inherently chaotic. By this is meant that the dynamic system that explains climate variations is highly sensitive to the initial situation. For a popular discussion of dynamical systems and chaos see Gleick (1987) and for a mathematical treatment see for example Devaney (1987). A dynamical system is a system that predicts the state - temperature, population size, GNP etc. in the next period from information of the present state. If these predictions depend non-linearly on the present state (i.e. if an increase in the atmospheric concentration of CO_2 this period with 10% implies a temperature change in the next

period different from 10%), then the system may be chaotic. This means, as was said above, that a small change in the present state will cause great changes in the predictions for the future periods. The models describing climate are highly non-linear and there are therefore reasons to assume that some aspects of their predictions are chaotic. This means in particular that it is impossible to predict with any precision the future! A small change in the assumptions regarding the present state will in the long run cause the system to change substantially. This is the so called butterfly effect: The beats of the wings of a butterfly in Africa may cause a hurricane in the Caribbean!

To this should be added the increase in risk following global climate change due to a more violent weather pattern. It is believed (but not universally agreed) that global warming will increase the frequency of heavy storms and hurricanes, droughts and in general the frequency of violent fluctuations in the weather. These fluctuations will not in general be predictable (except in a probabilistic sense), and will therefore add to the uncertainty. Furthermore, this uncertainty will remain even after climate change has taken place, that is they will tend to be permanent (at least over a foreseeable future).

Traditionally, the situation just described is described both in terms of risk and in terms of uncertainty (Knight 1977). The term risk is used when it is possible to attach probabilities to the various outcomes and the term uncertainty when this is not possible. However, this distinction is to a large extent not relevant for rational decision making. The reason being that rational preferences (where of course "rational" is defined in a special but very reasonable way) always can be represented by subjective probabilities and utilities in such a way that the rational choice is given by the choice that maximizes expected utility. Therefore, we will limit ourselves to the theory of risk.

VI. The expected utility hypothesis

The expected utility hypothesis, either as a norm for rational decision making or as a description of behavior vis-à-vis risk, has a very long history. It goes back to the St. Petersburg paradox. Consider a coin throwing game such that if the first time head shows is in n 'th throw, you will win $\$2^n$. How much would you be willing to pay for participating in the game? It is easy to see that the expected win is infinity, but no one would be willing to pay a high amount for the right to participate.

This is the paradox. It was resolved by Bernoulli, who argued that the "real" gains to the player was not the money gains but the utility derived from these monetary gains. Furthermore, he argued that, although the utility increases with the monetary gains, the rate of increase goes down with the monetary gains. Bernoulli postulated a logarithmic utility function, so that the utility of the monetary gain is simply the logarithm of the gain. With such a function it is easy to show that the expected utility is finite and that the player would be willing to pay only a finite amount for the right to participate.

The idea that one could and should use expected utility for analyzing uncertain prospects was introduced into economics (and social sciences in general) by Frank Ramsey (1931). However, it was in von Neuman's and Morgenstern's book *Theory of Games and Economic Behaviour* (1944) that the concept was derived from a small set of axioms describing what has been called rational decision-making. John von Neuman's and Oskar Morgenstern's contribution was so seminal that today we usually use the name von Neuman-Morgenstern utility whenever we discuss the expected utility hypothesis.

The axioms introduced by von Neuman and Morgenstern (the probably best presentation of the expected utility hypothesis is still Luce and Raiffa (1964) characterized preferences over uncertain prospects. A prospect is simply a lottery - a list of prizes (some of which can be negative) and the associated probabilities. One such prospect can be described as $L = (p_1A_1, p_2A_2, \dots, p_nA_n)$, where A_i is the prize if the i 'th outcome is realized and the probability for this is p_i . The list of n outcomes is complete, so that the probabilities add up to one. The problem we are going to study is how to choose between different prospects. Let L' be a different prospect $L' = (p'_1A_1, p'_2A_2, \dots, p'_nA_n)$. We have here assumed that the second prospect has the same list of prizes. This does not impose any limitation as we can use as the list of prizes the combined list for the two prospects. How should a decision-maker choose between L and L' ?

Von Neuman and Morgenstern introduced six axioms²:

1. The decision maker can rank the prizes $A_1, \dots, A_n$ consistently. This means that we can assume that the prizes are ordered in such a way that A_n is regarded as best, A_{n-1} next best, etc.
2. A compound prospect, i.e. a prospect in which the prizes are new prospects can be reduced to a simple prospect with prizes $A_1, A_2, \dots, A_n$ with probabilities calculated according to the laws of probability theory.
3. For each prize A_i , there exists a probability u_i so that the decision-maker is indifferent between A_i and the lottery $((1-u_i)A_1, u_iA_n)$. Let us denote this last lottery with B_i . Then the axiom says that the decision-maker is indifferent between A_i and B_i . This assumption is really an assumption of continuity and is usually interpreted as saying that to each uncertain prospect, there is a certainty equivalent, i.e., we can replace an uncertain prospect with a certain outcome and the decision-maker will be indifferent to such a replacement.
4. In any prospect, if we replace A_i with B_i , then the new prospect will be indifferent to the original prospect.
5. The preference among different prospects is transitive, i.e., if L is better than L' , and L' is better than L'' , then it follows that L is better than L'' .
6. A prospect $((1-p)A_1, pA_n)$ is preferred to a prospect $((1-p')A_1, p'A_n)$ if and only if p is greater than p' .

These axioms seem, at least at a first look, eminently reasonable. However, they are of course open to some severe criticism. We do not have space here to discuss them further but the reader is referred to a number of excellent presentations (Luce and Raiffa 1964, Machina 1987). It is now possible to show that if L is preferred to L' , then

$$p_1u_1 + p_2u_2 + \dots + p_nu_n > p'_1u_1 + p'_2u_2 + \dots + p'_nu_n.$$

This can then be interpreted as saying that the expected utility for the first prospect is greater than the expected utility for the second prospect. Thus, when analyzing choices between different uncertain prospects could simplify the analysis by using the expected utility hypothesis.

Whatever criticism one could raise against the axioms, one could argue that they include a minimum of conditions that would guarantee rational decision making. Therefore, the expected utility hypothesis is generally accepted as prescriptive device. An individual, an organization or society should behave in a way consistent with the axioms in order to be certain to behave rationally. However, it is a completely different matter whether individuals, organizations or society behave in a way consistent with axioms. Already in the early 1950's, Maurice Allais, Nobel prize winner in economics, constructed an example with a number of prospects and when different individuals had to choose between the prospects, they in general made choices not consistent with the expected utility hypothesis. After that, psychologists and economists have carried out a great number of laboratory experiments, the results of which seem to indicate that people do not behave in a way consistent with the expected utility hypothesis. In order to enable us to predict actual choices between uncertain prospects, alternative theories have been developed and tested. Machina (1987) surveys both the experiments and the recent development of new theories.

Even if experiments indicate that there are deficiencies in using the expected utility hypothesis in explaining individual behavior, it has been used with great success in explaining market behavior. For example, the successes in explaining insurance and financial markets³ as well as some commodity markets⁴ indicate that the expected utility hypothesis has explanative powers in many circumstances. However, more important for the analysis of equity issues in connection with global climatic change is that it is very useful for prescriptive analysis. We will therefore in the rest of the discussion of risk maintain the hypothesis.

VII. Other criteria

However, before continuing, a few remarks should be made on the assumption that there exists probability distribution over the possible outcomes. Although IPCC has

suggested an interval for the predicted future average global warming, it has not quantified the predictions by giving a probability distribution of the global temperature change. Of course, for local climate changes not even averages have been produced. It is therefore not straightforward how one should apply the expected utility framework.

There are a few criteria that could be used in decision-making in case there are no probability distributions over the outcomes. Once again, Luce and Raiffa (1964) gives a modern discussion of the appropriate theory which is still very much up to date. The different criteria respond in the literature can all be related to each other through various systems of axioms. Instead of describing these axioms, it will suffice for this purpose to discuss one particular criteria that is very much related to the precautionary principle. This is the well known maxi-min criteria. If the global community has a number of alternative strategies to choose among then each strategy can be characterized by the worst outcome that is associated with that strategy and the maxi-min criteria then means that we should select that strategy that maximizes this worst outcome. Its basis is the same as Rawls' criteria for equity which we will discuss in a later session. It is clear that it corresponds to the precautionary principle in the sense that it recommends that it looks at the worst outcomes and tries to avoid those strategies that will generate the worst outcomes. It is not possible to apply the criteria to global warming directly, as we must first solve the problems of international equity, i.e. how costs and benefits from different strategies should be shared by different countries. However, if one strategy would be a freeze of carbon emissions while a second would be business as usual, and if the worst outcome of the second strategy is worse than the corresponding outcome with the freeze, then the global community should choose to freeze the emissions. The maxi-min criteria is, however, rather conservative because it takes into account only the worst outcome and not the nature of the other outcomes from a strategy, and it may happen that appropriate concern of these other outcomes would lead to a different choice.

Maxi-min and other criteria are designed to be applied to situations with complete ignorance. In most cases, we are not facing such situations. The climatologist give us some guidelines to what the more likely outcomes will be even if they cannot generate objective probability distributions. That leads us directly to the notion of subjective probability. Savage (1951, 1954) has shown that with axioms similar to the ones used by von Neuman and Morgenstern but with extensions, it is possible to derive the existence of an a priori probability distribution over the sets of outcomes in such a way that the rational decision maker would behave as if he is maximizing expected utility. Furthermore, Savage designed a scheme by which these subjective probabilities could be revealed by letting the decision maker express preferences over a sequence of binary choice questions. Savage's approach has been extended in various directions, for a survey see ???. In view of this, we will in the sequel that the expected utility framework is the appropriate framework for the analysis of the cost of risk-bearing.

VIII. Cost of risk-bearing

From now on, we will assume that the expected utility hypothesis is the appropriate starting point for an analysis of the risks involved in global warming.

In estimating the cost of global warming and the cost of carbon abatement it is usually the expected cost that is estimated. Sometimes it is not even that but the cost associated with some special outcome, for example, the most probable outcome. These estimates are useful but neglect a cost component that may be substantial for some countries - the cost of risk bearing, if the utility is linear in the damage cost, then there would be a one-to-one correspondence between the expected utility and expected cost. However, usually there are no reasons to assume that utility is linear. In fact the St. Petersburg paradox arose from the assumption that utility was linear and in order to solve the paradox a non-linear utility was introduced.

In order to understand the meaning of the cost of risk bearing, consider a very simple case with two outcomes, A and B. In A the monetary gain is M_A and in B the gain is M_B . Let the probabilities for the two outcomes be p and $1-p$. The expected gain is then $pM_A + (1-p)M_B$ which we will denote by M . Is the decision-maker indifferent between the uncertain prospect $(pM_A, (1-p)M_B)$ and the certain gain of M ? If he is, he is said to be risk-neutral and if his utility function is u , it implies that

$$pu(M_A) + (1-p)u(M_B) = u(M) = u(pM_A + (1-p)M_B),$$

i.e., the utility function is linear. However, most evidence indicates that the utility function is concave, i.e., it increases with the gain but the rate of increase goes down as the gain goes up. This has the important implication that

$$pu(M_A) + (1-p)u(M_B) < u(pM_A + (1-p)M_B).$$

The individual would prefer the certain outcome M to the uncertain prospect, although they have both the same expected value. This also means that the individual would be willing to sacrifice an amount in order to ensure a certain outcome. This willingness to pay is defined as the c of risk-bearing. Let C be this cost. Then it is defined from

$$pu(M_A) + pu(M_B) = u(pM_A + (1-p)M_B - C).$$

C is the maximum insurance premium the decision-maker would be willing to pay in order to eliminate the uncertainty. If the uncertainty is not eliminated, then it is the cost he has to bear for that uncertainty.

These simple ideas have some powerful implications on equity issues in connection with global warming. There do not exist markets on which individuals or countries could insure themselves against impacts due to changes in climate or due to changes in abatement policies. This means that organizations will have to bear an unnecessary burden corresponding to the cost of risk-bearing. The establishment of global insurance markets would therefore increase efficiency in the global economy substantially. Furthermore, there are good reasons to believe that the distribution of the cost of risk-bearing is very uneven. First of all, industrialized countries have in general better insurance markets. This means that individuals in those countries can reduce their cost of risk-bearing substantially (but not completely, partly because global warming is a collective risk and partly because the incompleteness of markets). These possibilities are not open to most individuals in developing countries, and they have therefore to bear a higher cost of risk-bearing. Secondly, the cost of risk-bearing may be much higher in some developing countries than in industrialized countries because of the nature of the impacts. For example, a range from 20 cm to 60 cm may imply a quite low cost of risk-bearing in a country like USA and the expected damage would be a good proxy for the total cost of sea level rise. For a country like Bangladesh, the difference between 20 and 60 cm may mean a substantial difference in utility, which is not accounted for in the expected damage. For that reason, the cost of risk-bearing in Bangladesh is probably much higher than in other countries. The same holds true for countries that may be threatened by increase in both the frequency and the severity of droughts. The variation in utility will probably be much greater than the variation in actual damages among different outcomes and therefore, the cost of risk-bearing will be high. Unfortunately, there are hardly any empirical studies on the cost of risk-bearing and therefore there are no hard evidence that the hypotheses raised above are correct. But they do seem to be reasonable.

The conclusions to be drawn from this discussion are two.

- It is necessary to include the cost of risk-bearing in any equity discussion related to global warming. In particular, measurements of costs of impacts should also include this cost component in addition to expected cost.
- It is necessary to establish global markets for insurance against impacts from global warming.

IX Irreversibility

The problem of risk becomes more severe when changes in the environment are irreversible. The reason is that an irreversible change means losses of future options. This was studied by both Arrow and Fisher (1974) and Henry (1974) and they showed that the

combination of uncertainty and irreversibility implied that the expected net benefit is not the correct criteria to decide whether the irreversible change should be undertaken or not. In fact, on average, fewer irreversible changes should be made than what would be implied by the expected net benefits. The correct criteria should include a cost component known as the quasi option value, reflecting the expected value of the losses in options following the irreversible change.

There have been a substantial number of extensions of Arrow- Fisher's and Henry's analysis (Fisher Hanemann (???), Hanemann (???), Mäler (?r) etc. etc. However, there have been very few empirical applications of the basic ideas. The best known is Fisher Hanemann (1987) on the quasi option value of extinction of a specific species of Mexican rye. The theory has obvious bearings on the discussion of the economics of climate change, but there are no empirical studies at all.

Intertemporal equity

X. The time horizon

Before continuing the discussion on intertemporal justice, it is necessary to fix the time span in which we are interested. How far in the future should we be concerned with well-being? There are in principle two answers to the question. We could be satisfied with a finite number of time periods, say T years, during which we are concerned with human well-being. But we could also argue that we should look human well-being forever. It turns out that the choice of answer will be of profound importance for how we should look at intertemporal distribution of well-being.

With a finite time horizon, we always end up with the problem on how to evaluate what happens after the last time period. If we take the idea of a finite time horizon seriously we have to admit that what happens after the horizon is of no concern. But that implies that the well-being of generations living after the time horizon will not be accounted for¹. Thus, the interpretation of the notion of sustainable development we offered in the previous section seems to be contradictory to the idea of a finite time horizon. Logically we should therefore accept the notion of an infinite time horizon. As we shall see in the next section, this will carry with it some interesting and important implications.

We should also point out that this is true even when we take into account uncertainty about a possible end to human life (unless it is known that human life will expire at certain time). This uncertainty will of course affect the way we look at the welfare of future generations, but not the conclusion that we need to consider an infinite time horizon.

XI Impatience

What we now have to do is to find some representation of a social order of an infinite stream of utilities. However, in order to do that we have to make the judgment whether these utilities are bounded or not. This rather abstract, mathematical issue will have some rather important implications for the way we should look at intertemporal justice. Roy Radner (1974) and more lately Graciella Chichilnisky (1994) have argued that bounded utilities have important implications. We will return to their arguments later. For now, we will focus on the case when there are no *a priori* assumptions on the utility stream.

In a remarkable set of contributions, Koopmans (1960, 1965, 1967, 1972a,b) conducted a series of thought-experiments on intertemporal choice so as to see the implications of alternative sets of ethical assumptions in plausible worlds². Underlying Koopman's program of research was the premise that no ethical judgment in such abstract exercises as those involving resource-use should be taken as being, decisive. We should instead play off one set of ethical assumptions against another within plausible scenarios, see what their implications are for the distribution of well-being and then appeal to our varied intuitive senses before arguing policy. For example, he showed (Koopmans, 1965, 1967) that we can have no direct intuition about the validity of discounting future well-beings, unless we know something concrete about feasible development paths. As the set of feasible paths in a world with an indefinite future is enormously complicated, the reasonable thing would be to work with alternative discount rates on well-being and see what they imply³. Although seemingly innocuous, this suggestion represents a radical break with a philosophical tradition, stretching from Ramsey (1928) to Parfit (1984), that has argued against discounting future well-beings without first having studied its distributional consequences across generations in plausible worlds. That this tradition is otiose by Mirrlees (1967) and Chakravarty (1969), who showed that in plausible economic models, not to discount future well-beings could imply that the present generation be asked to save and invest round 50 per cent of gross national product. This is a stiff requirement when GNP is low.

For simplicity of exposition, let us assume that population size is constant over time (t), and that generation t 's well-being is an increasing function of its level of consumption (C_t), which we denote by $W(C_t)$. We assume time to be continuous. Let Γ_c be the set of feasible consumption paths - from the present to the indefinite future-, and let Γ_w be the corresponding set of well-being paths. We take it that there is no uncertainty, and that Γ_w is bounded. Imagine that there is an underlying ethical preference ordering defined over Γ_w . Alternative policies are therefore to be evaluated in terms of this ordering. Koopmans (1960) showed that under a plausible set of assumptions, this ordering can be represented by a numerical functional (which we may call aggregate well-being) possessing the "utilitarian" form:

$$(1) \int_0^\infty W(C_t) \exp(-\delta t) dt, \text{ where } \delta > 0.^8$$

Now (1) may look like classical utilitarianism, but it is not. There is nothing in the mans axioms to force a utilitarian interpretation upon W . Moreover, (1) involves discounting future well-beings at a constant rate ($\delta > 0$). In short, positive discounting of well-being is seen to be an implication of a set of ethical axioms that at face value at least, would appear to have nothing to do with discounting.

When conducting analytical experiments with alternative assumptions embedded in (1), it makes sense to go beyond the Koopmans axioms and allow for consideration the case where $\delta = 0$. It also makes sense to go beyond the axioms and to consider unbounded well-being functions. This way we are able to test models to see what all this implies for public policy and the choice of discount rates in social cost-benefit analysis. On the other hand, purposeless generality should be avoided. So we will assume that $W(C)$ is strictly concave, to give shape to the idea that intergenerational equity is valued as an ethics goal⁹

It is as well to begin by noting that discount rates in use in social cost-benefit analysis are 'consumption discount rates'. In first-best situations, they equal 'income discount rates'. (They are also sometimes, misleadingly, called 'social discount rates', and are different from market interest rates in second-best situations; see below.) If consumption is expected to grow, then the discount rate used in cost-benefit analysis would be positive even if δ were taken to be zero. This follows from the strict concavity of $W(C)$. To see this, recall that, in discrete time the consumption rate of discount at time t is the marginal social rate of indifferent substitution between consumption at times t and $t+1$ minus 1. This means that it is the percentage rate of decline in discounted marginal well-being over the interval $(t, t+1]$. Let ρ_t denote this. Reverting to continuous time and the 'utilitarian' form in (1), it is an easy matter to confirm that

$$\rho_t = \rho(C_t) = \delta + \alpha(C_t)[dC_t/dt]/C_t \quad (2)$$

where $\alpha(C_t) > 0$ is the elasticity of marginal well-being at t (see e.g. Arrow and z , 1970). Moreover, along a full optimum-4 the consumption rate of discount equals the productivity of capital (i.e. the social rate of return on investment). This is the famous Ramsey Rule.

Iso-elasticity offers a simple, flexible form of $w(\cdot)$. So let us assume that

$$W(C) = -C^{-\alpha}, \text{ where } \alpha \text{ is a positive constant.} \quad (3)$$

In this case the optimality criterion reflected in (1) depends only upon two parameters: α and δ . Obviously, the larger is δ , the lower is the weight awarded to future generations' well-beings relative to that of the present generation. The moral of Mirrlees's (1967) computations was that introducing this sort of bias would be a way of countering the

advantages to be enjoyed by future generations, should the productivity of capital and technological progress prove to be powerful engines of growth in well-being.

Nevertheless, consider the case $\delta = 0$. As an example, let us assume that $\alpha = 2.5$ (a not implausible figure if $W(C)$ were to be based on revealed preferences). If the rate of growth of optimum consumption at t is, say, 2 per cent, then $\rho_t = 5\%$. It will be noticed that the larger α , the more egalitarian is the optimal consumption path. As $\alpha \rightarrow \infty$, the well-being functional represented in (1) resembles more and more the Rawlsian maxi-min principle w applied to the intergenerational distribution of consumption (and thus well-being). This in turn means that, even in productive economies, optimal growth in consumption is slow if α is large. In the limit, as $\alpha \rightarrow \infty$, optimal growth is zero. From equation (2), we can now see why the consumption rate of discount is bounded (and how it manages to equal the productivity of capital) even in these extreme parametric terrains, (On this, see Dasgupta and Heal 1979, Chapters 9-10.)

Social discount rates are percentage rates of change of intertemporal relative shadow prices. It follows that unless the optimizing economy is in a steady state, social discount rates typically depend upon the numeraire that has been adopted¹⁰. As equation (2) makes clear, the well-being discount rate differs from consumption rates of discount, and it continues to be misunderstood in a good deal of the environmental literature that is critical of social cost-benefit analysis (see e.g. Daly and Cobb, 1991; Norgaard and Howarth, 1991). Modern philosophers writing on the matter make the same mistake and conflate well-being and consumption rates of discount. They argue that δ should be zero and then criticize the practice of discounting future flows of consumption in social cost-benefit analysis (see e.g. Parfit, 1984; Cowen and Parfit, 1992).

Although simple, the Koopmans formulation spans a rich variety of ethical considerations. Among other things, it tells us that consumption rates of discount do not reflect primary value judgments: they are derived notions. They are essential when we try to implement optimal policies by means of cost-benefit analysis of projects.

Notice that in equation (3), $W(C)$ is unbounded below. If $\delta = 0$, this ensures that very low consumption rates are penalized by the optimality criterion reflected in (1). On the other hand, if δ were positive, low consumption rates by generations sufficiently far in the future would not be penalized by (1). This means that unless the economy is sufficiently productive, optimal consumption will tend to zero in the very long run. As an illustration of how critical δ can be, Dasgupta and Heal (1974) and Solow (1974a) showed in a model economy with exhaustible resources that optimal consumption declines to zero in the very long run if $\delta > 0$, but that it increases to infinity if $\delta = 0$. It is in such example that notions of sustainable development can offer some cutting power. If by sustainable development we wish to mean that the chosen consumption path should as a minimum never fall short

of some stipulated, positive level, then it follows that the value of δ would need to be adjusted downward in a suitable manner to ensure that the optimal consumption path meet with the requirement. This was the substance of Solow's remark (see Solow, 1974b) that, in the economies of exhaustible resources the choice of δ can be a matter of considerable moment.

On the other hand, by sustainable development we could mean something else: we could mean that well-being (and, therefore, consumption) must never be allowed to decline. This is a stiffer requirement than the one we have just considered. If δ is less than the productivity of capital, the valuation criterion reflected in (1) ensures that the optimal consumption path will satisfy the requirement. This follows immediately from equation (2) and the Ramsey Rule. We may therefore conclude that the Koopman's program is all-encompassing, and that concepts of 'sustainability' are useful in pruning out of consideration those consumption paths that are ethically indefensible on *prima facie* grounds.

Let me very briefly add to this that one assumption underlying this discussion has been that well-being or utility has not been bounded. If we restrict well-being to be bounded, some other results will come about. This has to do with mathematical properties of the space of bounded sequences, and it turns out that for such sequences the present value calculations are not rich enough to catch all the subtleties of the evaluation of a utility stream. In fact, one has to add to the present value another term. In an ingenious interpretation, professor Graciella Chichilnisky (1994) has suggested that the first term, - the present value term - represents the requirement that the future should not be over the present and that the second term - the new term - represents the requirement that the present should not be a dictator over the future. This second term will in general have the form of a long term average. It could be approximated by minimum requirements for the long run stocks of environmental resources. With regard to climate change, one could imagine that the Chichilnisky criteria would be to minimize the total discounted damage and abatement costs from now and forever under the restriction that in the very long run, the climate must not exceed some bounds. Unfortunately, Chichilnisky analysis does not offer a way of finding these bounds. It is very difficult to have an intuitive appraisal of whether the utility stream should be allowed to be infinite or not when we allow for an infinite time horizon. But it is remarkable that these rather abstract mathematical facets may have an important ethical and economic impact. However, for this presentation, I will remain within the Koopman's framework, that is a present value calculation of the well-being of all generations.

XII. Measurement

From an ethical point of view, the important choice is the choice of δ , that is the pure time preference. How should it be chosen? From a practical and operational point of

view, the important choice is of ρ , the consumption interest rate. Typically, in the literature on cost benefit analysis, the chosen discount rate is based on market rates of interest. The argument being that the market rate will reflect the opportunity cost of capital. Sometimes it is argued that there is a need to correct the market rate because of market imperfections, such as capital income taxes (see Lind 1982, Dreze and Sandmo 1977). The result after these corrections would then reflect the consumption rate of discount. In a perfect world, with perfect markets and in which we are ethically neutral between the well-being of different generations, this will yield an acceptable estimate of the consumption rate. In fact, if the economy is expecting a reduction in productivity because of climate change, then the market rate of interest will also be expected to fall and if the impact from the climate change is serious enough, the return on capital may be negative with the result that we should discount the future with a negative interest rate!

However, we do not live in an ideal world and there are other imperfections that we have to account for. The most important one has to do with missing markets. The market rate of interest is determined through transactions in assets. However, only those assets that have well defined property rights can be subject to transactions and have an impact on the market rate of interest. This has some far reaching implications as most of our environmental resources - including our climate - has no property rights and it is in fact impossible to define property rights for many of these resources. Thus, the productivity of these resources does not directly influence the market rate of interest although in an ideal world they should. If we base our intertemporal equity considerations on the market rate of interest, that is the opportunity cost of real capital, we are excluding the productivity of our environmental resources from consideration.

Referring back to equation 2, we could argue that α may be negative because of deterioration of the environmental resource base - in this case the climate - while this would not be reflected in the market rate of interest. Thus, there is the possibility that the market interest rate gives no guidance at all for making intertemporal choices, but that we need some more elaborate ways of estimating the present and the future productivity of the total capital stock - human capital, real capital and natural capital - in order to make reasonable statements on how to compare future and present consumption bundles. Right now we do not have the data or the techniques available to do that. Undoubtedly, this a terribly important issue to be resolved in view of the possible consequences from climate policies.

The main conclusion is, however, that the choice of the consumption rate of discount is not something one could select independently of one's predictions of the future. If the IPCC predictions for the economic impact from climate change are very gloomy, then a low or even negative rate of discount would be appropriate, where if the predictions are rather optimistic, then the market rate (after corrections for other imperfections) may be the correct choice.

If there would be a perfect global capital market then of course, the same rate should apply in all countries. We do not have such a market. One reason being the lack of insurance, discussed above. This incident of missing market will also have implications for the choice of an interest rate. The market rate will in that country be higher in order to give the investors the necessary compensation for the increase in exposure to risk. However, with perfect insurance markets, the interest rate would be lower. Once again, the lack of insurance markets will have serious implications for the distribution of cost of impact, and it seems as important to address this institutional issue as it is to address the issues related to instruments to control emissions.

III Equity Among Regions and Countries

Draft contribution to IPCC chapter on Equity and Social Considerations

First draft by Michael Grubb

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III.1 Introduction

This part of the chapter considers equity issues between different countries. This has many different aspects, ranging from a variety of philosophical and other theoretical debates about meanings of equity and fairness, through a variety of aspects in which countries differ in practice, to debates about the implications of these factors for international policy towards climate change.

Various philosophical and other theoretical and definitional issues have been discussed earlier in this chapter [Jake]. The main focus in this section is upon the ways in which countries differ in ways that are relevant to the question of equity between countries in responses to climate change. The following section then reviews some of the issues and conclusions that writers have drawn concerning implications for policy towards climate change.

Equity is not the same thing as equality, but issues of international equity are clearly related to a variety of differences between countries. This review looks at five aspects which are of greatest relevance and which feature most in the literature, namely:

- Wealth and consumption
- Social considerations and institutional capabilities
- Emissions - past, present and future
- Impacts - the distribution of and vulnerability to climate change
- Endowment with resources that may be affected by responses to climate change

III.2 Wealth and consumption

Wealth is one of the most obvious and pervasive differences between countries. Much of the literature on international equity starts from this issue, and the statistics need little elaboration. Figure 1 shows the distribution of average per-capita income between

[countries/regions: best source: WDR?] on convention [&/or PPP?] exchange rates. On this basis, the one-fifth of the world's population in the richest countries account for XX% of the world total GNP; the poorest one fifth account for XX%.

In human terms these differences have a direct bearing upon the issue of climate change in various ways. Activities of the poor that result in emissions of greenhouse gases are mostly those that relate most closely to "basic needs" often at little more than subsistence levels - energy for cooking or keeping tolerably warm, emissions from agricultural activities, perhaps energy for light to enable reading, and occasionally for travel by public transport. Emission from the rich tend to be dominated by activities such as driving private cars, home central heating, and energy embodied in a wide variety of manufactured goods and the use of such goods. The welfare impacts of cutbacks of greenhouse gas emissions may thus differ greatly according to the level of personal wealth. [Ref: Basic Needs literature (Chichilnisky; others? Agarwal, etc.)]

Obviously there are great variations within countries, but in aggregate the same broad issues apply concerning wealth disparities between countries. The aggregate relationship between wealth, consumption of a variety of natural resources, and emissions of various pollutants have been explored methodically by a number of authors. Using cross-sectional data [. expand?], Parikh shows that consumption of a wide variety of resources - many of which involve emissions of greenhouse gases in their extraction, processing and application - is closely related to the level of wealth [Figure?]. Williams [+ others] argues that in many developed economies, a decoupling of wealth from material consumption has occurred since the 1970s and that this will accelerate, though others have disputed this []; but the aggregate relationship at middle and lower income levels seems undisputed. The 1992 World Development Report notes that direct emissions of many pollutants declines beyond a certain stage of economic development, but considers that this point has not been reached for most greenhouse gases, particularly CO₂ and (to a lesser extent)

CH₄ from sources other than land use.

Wealth is thus not only one of the most important determinants of greenhouse gas emissions (at present). It also has a very important bearing upon vulnerability to climate change. [expand here, or below]

Poverty also has an important bearing upon national priorities and the time scales considered in policy. Economists have long noted that personal discount rates decline with rising income (is there standard ref?). Richer people can afford to look further ahead, have greater security, and can afford to invest more for the future. Poor people are focused more upon short-term concerns, including those of striving to ensure that they can meet

basic needs. This has important implications for the potential equity impact of policies to address climate change within countries [as noted above - Tariq?] and the same applies at the level of national economic and political systems.

Thus, in poorer countries interest rates tend to be higher, capital is scarcer, and the whole focus of policy and politics tends to be upon meeting pressing short-term needs ranging from poverty alleviation and employment generation to the management of fiscal crises, often driven partly by the needs of debt repayment. At the industrial level, the focus may for example be upon the scramble to construct infrastructure and capacity fast enough to meet rapidly rising demand, rather than the more considered examination of optimal investments over longer periods that may be possible in richer countries. Thus the context both for actual investment behavior and broader public policy is strongly affected by national wealth in ways that are directly relevant to the climate problem (Mathur, others.).

III.3 Social considerations and institutional capabilities

The importance of social considerations and institutional capabilities has been considered in the previous section. The important point here is to note the extent to which countries differ in these respects.

III.4 Patterns of greenhouse gas emissions

Discussion of patterns of historical, current and projected emissions, based on my co-authored "sharing the burdens" paper review and some more recent work (IPCC?), and noting Agarwal, Meyer etc. points about ways of presenting.

III.5 Impacts of climate change

Focusing upon:

- distributional nature of physical impacts (sea level, storms, drought etc.).
- differential susceptibility
- differential capability to adapt Concluding with discussion of:
- time lags involved
- implications for damage evaluation

III.6 Resources that may be affected by responses to climate change

III.7 International equity considerations in responding to climate change

III.7.1 Introduction

The previous section has addressed the principal differences between countries that are relevant to the subject on international equity: differences in wealth, institutional capabilities, emissions, resource endowments, and vulnerability to climate change. This section considers the implications that these differences, when combined with various principles of equity, may have for international responses.

In addressing these questions, several points need to be made at the outset. No international agreement has ever been founded purely on a logical consideration of equity issues; a whole range of other factors, ranging from basic economic and political power structures to accidents of timing and personalities, influence the outcome. Yet nor is the converse - the cynical view that equity considerations play no role at all in the real world of international politics - true. Analysis of possible agreements based upon game theory (especially "single shot" or non-repetitive games), conducted purely from the point of view of maximizing self-interest, point towards outcomes with little or no explicit equity content, but often do not explain agreements that have been reached.

Furthermore, a broader view of self-interest often point towards more explicitly equitable outcomes because of the longer-term risks that grossly inequitable behavior may pose to stability and cooperation in the international system. This chapter however is not concerned directly with such broader conceptions of self-interest, but rather with equity *per se*.

Second, there are many inequities in the world, between and within countries, and it is no more realistic to suppose that climate change can be a vehicle to resolve all the international inequities than to suppose that it can resolve all the inequities within countries. But there is an important difference. Within countries, institutions exist to address a wide range of issues of common interest to members of that society. The institutions have developed in part to provide a way of taking decisions about constitutes acceptable behavior, and decisions about the distribution of wealth and resources - in most countries, through regulation of market structures backed by legal codes and with progressive taxation as a way of redistributing resources to common goals.

Equity - in the form of views about what constitutes social justice - is an important influence and measure of the legitimacy of these institutions and their decisions. The actual strength and perceived legitimacy of these institutions varies widely, but policies to

address climate change at the level of national implementation fall clearly within the remit of these institutions and processes.

The institutional parallels at the international level are weak or non-existent. Yet in responding to climate change, humanity faces unavoidable decisions about the distribution of effort and burdens, and what constitutes acceptable behavior, in circumstances where the internal activities of one country may directly impact upon all others. Whilst on a modest scale there are precedents (e.g. with ozone depletion, commodity cartel pricing decisions etc.), climate change is wholly unique in the scale and scope of its potential implications. Whether or not countries seek to use climate change to try and resolve inequities in other areas, therefore, the relative weakness of international institutions may need to be compensated by great explicit emphasis on considerations of equity. Climate change and responses to it should at the very minimum not worsen existing inequities (Shue, *The Unavoidability of Justice*).

Finally, it should be noted that the applied research literature on these questions - relating specifically to climate change policy - is limited compared to that on climate science, impacts or the economics of responses. There are of course many short articles and statements of positions made in newspapers, newsletters, 'non-papers' at negotiating sessions, etc.; and also some important official declarations developed through extensive discussions to reflect consensus positions among groups of countries (e.g. the Beijing Declaration, and various regional statements). Also, the UNCED agreements themselves contain innumerable references related to equity. Most of this is cast in North-South terms, with important additions concerning the interests of particular groups.

The following section attempts to reflect this material, whilst recognizing the impossibility of ensuring comprehensive coverage, and drawing heavily upon the limited deeper analysis of international equity issues in the more conventional academic literature of books, substantive reports and articles in peer-reviewed journals. Interestingly, of those that have contributed such analysis, few are professionally employed as academics in the discipline which might seem to be of greatest direct relevance - moral philosophy. In structuring the remainder of this chapter we draw upon the observation by one such philosopher (Shue, 1992) that the equity issues comprise at least four distinct questions:

- distribution of the costs of coping with climate change
- distribution of future emissions
- distribution of the costs of measures to limit emission
- the background allocation of resources and capabilities and consequent basis for fair bargaining

All these questions are interrelated. For example, a "fair" distribution of future emissions may depend somewhat upon how much countries help others with the costs of coping; a

fair distribution of abatement costs depends upon various background circumstances; and debates about joint implementation and tradable emission quotas highlight a potentially strong link between ii) and iii). Few authors in fact have distinguished these different components; but they are distinct and it is useful to address the equity issues each raises in turn, even if two or more of them may in practice be tied or even addressed through the same instruments.

III.7.2 Who should pay for the costs of coping?

If there are no international transfers or other assistance connected directly with the measures to cope with actual or potential impacts of climate change, each nation in effect is expected to cope using its own resources. The available literature appears to be unanimous in considering this inequitable, for two main reasons.

The first arises directly from the observation above that poor countries are likely to be much more vulnerable to climate change. Climatic change is thus likely to exacerbate existing inequalities. Most ethical systems would anyway expect richer parties to contribute more to addressing a common problem; the rationale is much stronger still when the cause is shared but the impacts are disproportionately large on the least well off parties.

The second factor, which applies irrespective of this inequitable distribution of impacts (but is much reinforced by it) is the direct causal link: the fact that the actions of some people (emitting greenhouse gases) may directly harm others. There are few if any ethical systems in which it is acceptable for one individual knowingly to inflict potentially serious harm upon another and not accept any responsibility in helping or compensating the victim, or to pay in some other way. None of the literature attempts to present reasons why the same principle should not apply concerning transboundary impacts potentially arising from climate change.

Indeed, this is a point which was formally accepted at the intergovernmental level in Principle 21 of the Stockholm Declaration, and more explicitly in Principle 13 of the Rio Declaration: [XX]. This 'fault-based' rationale aligns closely (though not perfectly) with that arising from the likely distribution of impacts: poorer nations tend to be more vulnerable, and richer nations tend to be greater past and current emitters of greenhouse gases. It is also an issue for which historical emissions are of direct relevance, since climate impacts are a function of atmospheric concentrations which depend strongly upon the cumulative emissions.

There are three broad kinds of costs that may be incurred in coping with climate change:

- i) preparation (or protection) to minimize the potential impacts of climate change, for example through the construction of sea defenses, improved water storage or water transfer capabilities, or changing the kind or diversity of crops;
- ii) costs arising directly as a result of changes in the resource base (e.g. loss of land to the sea, other loss of agricultural land), and the social costs that may follow from this (ref Suleman above?);
- iii) costs caused directly by extreme events, such as freak storms and droughts.

Although the underlying equity issue of who should pay is similar in each case, some of the practical issues differ. Even if there is agreement on the underlying equity principles, major practical differences and disputes may arise because of all the uncertainties surrounding climate change. General protection measures (i) have multiple benefits; views will differ on the extent to which they should be funded primarily on the basis of concerns about climate change. It is likely that victims of both underlying climatic changes (ii) and extreme events (iii) will attribute their suffering to human-induced climate change more readily than those responsible for the emissions. Insofar as international help is based on the second 'fault-based' rationale, this raises important issues about fair processes for deciding about the probability of events being tied to human-induced climate change, which none of the literature addresses explicitly.

The different nature of these costs has also led to different proposals about how to tackle them. Notably, there have been suggestions [detailed references sought: Beijing Declaration?] for a "climate fund" to help developing countries pay for protection measures (i); whilst the small island states have proposed creating an insurance pool to provide some cover against the costs of extreme events (iii).

The proposal for an insurance pool against the impacts of sea-level rise and associated salt intrusion and storm surge damage - put forward as an Annex to the draft Climate Convention but removed at a late stage under pressure of the Rio deadline - appears to be the most developed proposal. Wilford (1993) notes several reasons why commercial insurance markets cannot adequately cover against such risks and even to the limited extent they can the insurance premiums would presumably fall primarily upon the potential victims and thus represent an inequitable burden. Consequently, AOSIS proposed that an insurance pool be created with international funding from governments. Two precedents are noted:

- The 1971 International Convention on the Establishment of an International Fund for the Compensation for Oil Pollution Damage, which is funded by agreed levies on oil importers; and
- the 1963 Brussels Supplementary Convention (an OECD agreement, amended by 1964 protocol) to the 1960 Paris Convention on Third Party Liability in the field of Nuclear Energy. This is funded half on the basis of GNP, and half on the basis of nuclear capacity.

The draft Insurance Annex to the Climate Convention proposed, by analogy with the nuclear precedent, funding through a combination of GNP and CO₂ emissions, the latter component suggested both on grounds of responsibility and to give an incentive to limit emissions.

The main criterion for entitlement to claim was proposed as proved loss attributable to sea level rise, including storm surges. However, discussion of the proposal does not attempt to explain why the principles involved should be restricted to the case of sea level rise; it would appear more equitable to extend the scope of such a fund to insurance against all kinds of climate impacts. The literature does not appear to explore this issue, nor does the question of compensation or other support for other kinds of climate coping appear to have been explored more fully.

III.7.3 Abatement equity in the absence of substantive and separated international transfers

III.7.3.1 Introduction

Issues of how future emissions (or abatement efforts) should be allocated, and who should pay for abatement, form some of the most contentious equity issues in climate policy. As noted above, the two questions are closely intertwined. This section considers questions of fair distribution of emissions - and by implications abatement effort - separated from any substantive financial transfers related to climate change. The distribution of emissions / abatement effort then directly determines the payments, and any abatement-related transfers would be similarly determined directly by the initial emissions allocation, through the mechanisms of joint implementation or by more formal emissions trading. The subsequent section then considers other approaches which consider directly the question of 'who should pay' abstracted from the question of distribution of emissions.

There are three reasons for dividing the issues in this way. First, it provides a useful way of classifying the literature: although much of the general writing does not explicitly distinguish issues of who should pay from emissions distribution, most of the

more analytic material in practice focuses upon one or other as the "output". Second, it provides an analytically clear delineation which may help to remove some of the confusion in understanding the literature.

Much of the economics literature assumes that an international market - mediated by large international transfers to produce a global least-cost response - exists or will naturally come into being. This debatable assumption explains much of the division between economic and other perspectives. Third, by the same token it provides a politically useful clarification; many are skeptical of the prospects that an international fund, with payments though it on some equitable basis on support of a globally optimal response, will in reality ever be created, and this explains much of the fear about inequitable global responses. Focusing initially upon allocation in the absence of big international transfers helps to clarify these issues.

It is also useful to distinguish short-term from long-term allocation issues. In the long term, decisions will have to be taken - by design or default - about the overall allocation of greenhouse gas emissions. The appropriate allocation depends upon the conception of equity, and different ethical approaches may have very different implications. But in the short term, the position is simpler. All ethical systems, and all the applied literature, appears to point in the same direction (Shue, 1991):

'Even in an emergency one pawns the jewelry before selling the blankets... whatever justice may positively require, it does not permit that poor nations told to sell their blankets [compromise their development strategies] in order that the rich nations keep their jewelry [continue their unsustainable lifestyles].'

This much has been formally agreed in the Framework Convention on Climate Change: 'developed countries shall take the lead ...' [get full cite]

The observations about what is not fair in initial distribution of emissions obligations extends to other measures of abatement effort. Notably, some earlier and overly simplified economic studies assumed that a uniform carbon tax, as an indicator of abatement effort, would distribute the "burden" equally, fairly, and efficiently. None of these three suppositions have stood up to closer scrutiny in the literature:

- A uniform carbon tax would not impose equal burdens upon different countries because of differences in existing tax structures (Shah and Larsen; OECD; etc.), resource endowments (Whalley and Wigle; others?); and stages of development;

- even in a scheme involving "equal burdens," most observers argue that this would not be fair because of the many differences outlined in the previous section, notably differences in historical and current emissions and current wealth and consequent priorities;
- a uniform tax would also be Pareto-inefficient in the absence of optimal international lump-sum transfers, because of the differing marginal utilities between countries at different stages of development (Chichilnisky 1993a).

The literature thus demonstrates a degree of consensus about relative responsibilities and equitable directions of response in the short term, and some elements of what would not be equitable in longer term allocations. Beyond this, and in the attempt to develop more precise allocation principles, there is a far wider range of perspectives, which derive from a range of ethical approaches. These may be classified in three broad categories: ad-hoc proposals; general distributional principles; and specific allocation proposals. These are considered in turn.

III.7.3.2 Ad-hoc allocation schemes

Various ad-hoc allocation schemes have been proposed. Krause et al (1993) suggest that an overall cumulative limit for emissions of 300GtC over the next 100 years be established and divided equally between the current industrialized and developing countries. The general characteristics of this allocation are argued to be ethically appealing - it requires substantial cutbacks from the industrialized world and allows for some interim growth from developing countries - but no more detailed division is offered and no more formal justifications for a 50:50 aggregated division of future emissions are presented. Westing (1989) suggests land area as a basis for allocation, but without any particular justification and with some perverse consequences (Grubb et al, 1992).

More widely suggested is some proportion of GNP; Cline (1992) [others?] for example suggests that this could be a component of an allocation on the grounds that carbon emissions are partially tied to economic activity. But the relationship is quite variable between countries for a variety of reasons, and pure GNP allocation faces the objection that on its own it would directly reward riches, thus exacerbating inequalities - especially since poorer countries generally have lower GNP/carbon ratios (there could also be technical difficulties associated with definitions and manipulation of GNP comparisons).

III.7.3.3 General distributional criteria

Proposed general principles for emissions allocation appear to fall into three broad categories.

Rawlsian criteria.

One approach derives directly from the philosophical approach developed by John Rawls (1971). This considers the allocation that an observer might propose before knowing which country he or she belonged to (the "veil of ignorance"). For many, this leads to the principle that allocation should seek to most improve the position of the least well-off. At a minimum this would suggest that developing countries be left at least as well-off under an emissions control regime as they would be in its absence. A stronger interpretation would be that the regime should be used to seek to improve their position. [ref Knordsvel]

A related version of this is to place the emphasis upon basic needs, or defining a "reasonable level" of emissions for each country - a level that would support a consistent, modest standard of living, given the national climatic or other conditions. Allocations would be granted for emissions at this level, but not for those "luxury" emissions exceeding this. The actual level - presumably somewhere between survival emissions and reasonable comfort - and the extent to which it might vary between countries if at all, is of course somewhat ambiguous.

Comparable burdens

Another general approach to emissions allocation is the sentiment, frequently stated but not subject to more detailed analysis, that allocation should affect all countries similarly or involve "comparable burdens," or "sharing the effort equally." This is not to imply that countries should incur the same monetary costs (e.g. per capita); some conceive of it as a fixed proportion of GNP, others in terms of a more general measure of ability to pay, including more complex measures (e.g. the Human Development Index - see below). A strictly economic interpretation of "comparable burdens" can also arise from purely economic considerations in terms of Pareto efficiency. Chichilnisky (1993) demonstrates that if there are no big international transfers and each country has the same, convex utility function: at a Pareto-efficient allocation, the fraction of income which each country allocates to carbon emission abatement must be proportional to that country's income level, and the constant of proportionality increases with the efficiency of the country's abatement technology. This is the only distribution of abatement effort, for a given global total abatement, in which no country can be made better off without making another worse off.

Willingness to pay.

Another principle is simply that countries should bear costs based upon what they are - or objective "should" be - willing to pay, given the potential damages they face from climate change. According to this principle, contributions should be determined by a combination of ability to pay (reflecting current wealth) and, national benefits gained in terms of reduced climatic stresses, and level of general concern about climate change. This approach reflects the principle of welfare economics that subjectively perceived

enefits ought to affect the distribution of burdens (and hence allocations). Dorfman (1991) draws the important distinction that for a common property resource (degradation of the atmosphere), willingness to pay should be based not on how a country values a reduction in its own emissions, but instead, how much it would value a reduction in worldwide aggregate emissions. Presumably those valuing such reductions to a greater extent should be more willing to abate. One concern is that this could lead to a situation "victim pays," though in the greenhouse case the wealthiest countries are likely to be both the greatest polluters and the most willing to pay. At present an intractable difficulty is the lack of knowledge concerning the regional impacts of climate change, and in practice such a criteria would imply piecemeal negotiations in which each country had an incentive to underestimate the potential damages from climate change, and overestimate the costs of abatement, so as to obtain a lax allocation for itself.

These various principles can be extended to incorporate some differences other than those arising from differences in wealth, for example those arising from different source endowments.

1.7.3.4 Specific equity-based allocation proposals

The approaches outlined in the previous subsection offer general criteria, but do not give specific rules that could determine a unique allocation of emission entitlements. The number of such specific, equity-based proposals is in fact very limited.

Equal per-capita entitlements.

The most widely cited specific proposal for allocation in the literature is that derived directly from egalitarianism, suggesting that all human beings should be entitled to an equal share of the atmospheric resource. This takes two general forms, with minor variations.

Equal contemporary entitlements - allocation in proportion to national population - proposed by Grubb (1989), Bertram (1989, 1992), Epstein and Gupta (1990), and Sarwal and Narain (1991), among others. To prevent this providing an inducement to population growth, Grubb (1989) suggests that it should be restricted to adult population; Grubb et al (1992) note a wider range of possibilities for such decoupling including allocation tied to population a fixed period earlier, apportioned to a fixed historical date, including an explicit term related inversely to population growth rate. The net effect in all cases would be to give developing countries, with much lower per-capita emissions, a substantial excess entitlement, whilst the industrialized countries, with emissions well above the global average, have a deficit.

This effect is much stronger still in proposals for equal historical or stock entitlements. Fujii (1990), Ghosh (1991) and Meyer (1992) propose that everyone should have an equal right to identical emissions regardless of country and generation, and develop detailed systems of accounts involving intergenerational transfer of the responsibility for past excess per-capita emissions by the industrialized countries.

Egalitarian allocation, in either form, would be compatible with some of the more general principles noted above (such as Rawlsian) but not others (such as comparable burdens and willingness to pay).

Status quo.

At the opposite end of the spectrum, an alternate principle for emissions allocation has been suggested - but not necessarily advocated - for example by Young and Wolf (1992) as "status quo" - not only that past emitters should be held harmless but that their current rate of emissions constitutes a status quo right now established by past usage and custom especially since past carbon emissions were not generally regarded as damaging. Analogies are drawn with the common law claims of "squatter's rights."

A strict status quo allocation - proportionate to current emissions - would violate all the more general principles outlined in the previous section. In fact, none in the literature appear to advocate strict status quo as an equity principle in its own right. It has however received widespread reference as a basis from analysts taking a pragmatic or game-theoretic approach (e.g. Barret, 1991), in that it is the default allocation that would arise in the absence of agreement (and hence a focal point), and the only specific allocation basis which does not automatically impose big burdens upon the industrialized countries. In such treatments the ethical basis, where considered, is usually referred back to concepts of equal burdens. It should be emphasized that in this context 'status quo' is not a static concept, but rather refers to starting from a baseline of what emissions would have been in the absence of abatement, and thus would allow for more rapid growth from developing countries.

Mixed systems

An alternate form in which historical contributions are considered as a determinant of emissions allocation, other than historical egalitarianism, is a scheme examined by Grubler and Nakicenovic (1991) in which countries have to cut back from current levels in direct proportion to their responsibility for past increases. In a sense therefore this is a mixed system. In requiring cutbacks from all countries - albeit more from the richer countries - it is probably inconsistent with the other principles sketched in the previous section.

Cline proposes an alternate mixed allocation which combines population, GNP and current emissions. Grubb and Sebenius (1992), supported by Shue (1993) suggest an allocation which combines egalitarian and status quo / comparable burden principles, as a weighted mix of population and current emissions, and argue that the weighting accorded to population should increase over time.

III.7.4 Distributing costs with international transfers

The discussions above have focused upon the equity issues raised by different possible approaches to distributing emission "entitlements," irrespective of international transfers. In practice, most analysts suggest that both equity and efficiency considerations suggest a case for large international resource transfers as part of any regime for substantial reductions in greenhouse gas emissions.

Three main approaches have been taken to consider how, and how much, such transfers might occur.

III.7.4.1 Basis of the Climate Convention

One is based upon the principles in the Climate Convention, which states that [incremental costs]

This effectively divides the world into three groups. [Expand convention Annex 1 & 2 & developing countries / GEF / Joint Implementation]

III.7.4.2 Transfers determined by emission allocation and tradable entitlements

A second approach to international transfers is to let them be generated directly by determining a fair initial allocation, and allowing these entitlements to be traded (UNCTAD study). Since most of the allocation proposals noted above would give poorer countries entitlements greater than their needs, and leave richer countries with a deficit, this would generate a transfer of resource to the poorer countries. The initial allocation would be the principle means of determining resource transfers.

A number of concerns have been raised about practical aspects of such systems, including their possible fairness in operation without institutional safeguards. Several analysts, including both those supporting and opposing tradable entitlement schemes, have raised concerns about the equity implications of allowing countries to sell the "right" to emit. For this reason, it has been proposed that entitlements should be either leasable (Grubb 1989; Agarwal and Narain 1991), or issued with a finite lifetime (probably overlapping)

and reissued periodically according to the agreed allocation scheme (Bertram 1992, Grubb and Sebenius 1992). III.7.4.3

Polluter pays principle and historical responsibility

Bring in Natural Debt here

III.7.4.4 Ability to pay proposals

Smith / Hayes proposals on HDI index here

III.7.4.5 Mixed systems

Smith / Hayes 50:50 payment matrix here.

III.7.5 Process fairness in climate change negotiations

This is the section I most wanted to complete before going away for comment -but as you can see I haven't managed it. The main references I have to go on seem disconcertingly dated, and are:

Millennium special issue 19:3, Winter 1990

Policy Studies special issue 19:2, 1991

For Earth's Sake - report of Commission on developing countries and global change
Global Accord (Choucri, editor) 1994

I will insert box on Joint Implementation as a focus and illustration of equity issues.

Concluding section? Pointing towards process of building international rules?

One thing I haven't brought into this is the issue of "free riding" which initially we were asked to address, unless in the simplistic sense I have indicated in iv) above, I am not clear what else it might encompass that we should address?

V Equity Within Countries

To be supplied by Tariq Banuri.

Conclusion

To be supplied by the lead authors.

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Notes

1. The article refers to "developed country Parties and other Parties included in annex I. Annex I lists the European Community and 35 states, the 24 members of OECD in 1992 (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States of America) and 11 European states that are undergoing the process of transition to market economies (Belarus, Bulgaria, Czechoslovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russian Federation, and Ukraine).

2 The number of axioms differ between different presentations, but they all are essentially equivalent.

3 See Copeland and Weston (1983) for an introduction to financial markets and Borch (1977) for a discussion of insurance.

4 Newbury and Stiglitz (1987) is good example of this.

5 The idea of an infinite time horizon has a long history in economics from Ramsay (??), Samuelson, Tinbergen, Koopmans...

6 For an account of this programme, see Dasgupta and Heal (1979, Chapters 9-10).

7 Dasgupta and Heal (1974) and Solow (1974a) provide exercises of this sort in economies with exhaustible resources.

8 Koopmans's theorems were proved under the assumption that time is discrete. In Koopmans (1972a,b) the ethical axioms are imposed directly on T_c , and $W(\cdot)$ is obtained as a numerical representation.

9 For simplicity of exposition, we will begin by focussing on a full optimum. In Section 9, when commenting on cost-benefit analyses of policies to combat global warming, we will look at second-best situations. Social cost-benefit analysis in second-best circumstances was the subject of discussion in Dasgupta, Marglin and Sen (1972) and Little and Mirrlees.

10 Therefore, unless the numeraire has been specified, the term 'social discount rate' is devoid of meaning.

Table 4.4.3 Growth rates of population, GDP, primary energy consumption and CO₂ emissions in reference and abatement scenarios for 1990 to 2020/30.

COUNTRY	POPULATION	GDP	PRIMARY ENERGY		CO ₂ EMISSIONS	
			Reference	Abatement	Reference	Abatement
ARGENTINA (1)	1.1	2.0	1.8	1.1	1.8	1.1
BRAZIL	1.4	4.7	3.5	3.7	5.3	3.2
BRAZIL (1)	1.2	3.2	2.5	1.0	2.8	0.8
CHINA (6)	0.8	6.0	3.1	2.7	2.6	2.1
EGYPT	1.7	5.0	3.2	1.4	3.8	1.4
GHANA (5)	2.9	4.0	3.6	3.0	5.4	5.0
INDIA	1.8	6.3	4.2	3.8	3.8	2.9
INDIA (1)	2.0	5.0	4.6	4.3	4.6	4.3
INDONESIA (1)	1.2	3.0	3.6	3.2	4.0	3.5
SOUTH KOREA (4)	0.4	5.0		3.1		2.8
MEXICO (1)	1.7	4.4	2.7	2.1	2.8	1.9
NIGERIA (5)	3.0	4.0	2.6	1.9	4.6	3.8
SENEGAL	3.0	3.2	3.2	2.4	3.5	2.6
SIERRA LEONE (5)	2.3	3.0	2.2	1.7	3.5	3.0
THAILAND	0.9	4.8	4.8	4.2	5.5	4.6
THAILAND (4)	2.0	8.0		7.8		7.8
VENEZUELA	2.1	3.8	2.5	1.9	3.1	2.1
VENEZUELA (1)	1.7	4.0	3.4	3.2	2.5	1.9
ZIMBABWE	2.4	4.2	2.8	1.9	3.2	1.5
LATIN AMERICA (2)	1.5	3.3	2.7		3.2	
LATIN AMERICA (3)	1.3	3.2		0.9		-0.6
SOUTHEAST ASIA (2)	1.4	4.6	3.9		5.1	
SOUTHEAST ASIA (3)	1.6	4.1		1.5		-0.2

(1) Energy & Environmental Division, LBL; CO₂ Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term; July 1991.

(2) IPCC, 1992; Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment.

(3) Stockholm Environment Institute - Boston Centre Towards a Fossil Free Energy Future; April 1993.

(4) Asian Energy Institute; Collaborative Study on Strategies to Limit CO₂ Emissions in Asia and Brazil; 1992.

(5) Davidson Olungade; Carbon Abatement Potential in Western Africa; in P. Hayes, K. Smith, eds., The Global Greenhouse Regime: Who Pays?; 1993.

(6) Asian Development Bank; National Response Strategy for Global Climate Change: People's Republic of China; Nov. 1993.

Unnumbered studies were part of the UNEP GHG Abatement Costing project.

Table 4.4.4 Key elasticities in reference and abatement scenarios for 1990 to 2020/30.

Country	REFERENCE			ABATEMENT		
	Energy/GDP	C/Energy	C/GDP	Energy/GDP	C/Energy	C/GDP
ARGENTINA (1)	0.9	1.0	0.9	0.6	1.0	0.5
BRAZIL	0.8	1.5	1.1	0.8	0.9	0.7
BRAZIL (1)	0.8	1.1	0.9	0.3	0.8	0.3
CHINA (6)	0.5	0.8	0.4	0.5	0.8	0.4
EGYPT	0.6	1.2	0.8	0.3	1.0	0.3
GHANA (5)	0.9	1.5	1.4	0.8	1.7	1.3
INDIA	0.7	0.9	0.6	0.6	0.8	0.5
INDIA (1)	0.9	1.0	0.9	0.9	1.0	0.9
INDONESIA (1)	1.2	1.1	1.3	1.1	1.1	1.2
SOUTH KOREA (4)				0.6	0.9	0.6
MEXICO (1)	0.6	1.0	0.6	0.5	0.9	0.4
NIGERIA (5)	0.7	1.7	1.1	0.5	2.0	1.0
SENEGAL	1.0	1.1	1.1	0.8	1.1	0.8
SIERRA LEONE (5)	0.7	1.6	1.2	0.6	1.8	1.0
THAILAND	1.0	1.2	1.1	0.9	1.1	1.0
THAILAND (4)				1.0	1.0	1.0
VENEZUELA	0.7	1.3	0.8	0.5	1.1	0.6
VENEZUELA (1)	0.9	0.7	0.6	0.8	0.6	0.5
ZIMBABWE	0.7	1.2	0.8	0.4	0.8	0.4
LATIN AMERICA (2)	0.8	1.2	1.0			
LATIN AMERICA (3)				0.3	-0.7	-0.2
SOUTHEAST ASIA (2)	0.8	1.3	1.1			
SOUTHEAST ASIA (3)				0.4	-0.1	0.0

(1) Energy & Environmental Division, LBL; CO₂ Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term; July 1991.

(2) IPCC, 1992; Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment.

(3) Stockholm Environment Institute - Boston Centre Towards a Fossil Free Energy Future; April 1993.

(4) Asian Energy Institute; Collaborative Study on Strategies to Limit CO₂ Emissions in Asia and Brazil; 1992.

(5) Davidson Olungade; Carbon Abatement Potential in Western Africa; in P. Hayes, K. Smith, eds., The Global Greenhouse Regime: Who Pays?; 1993.

(6) Asian Development Bank; National Response Strategy for Global Climate Change: People's Republic of China; Nov. 1993.

Table 4.4.5 Marginal (MAC), Average (AAC) and Total Abatement Costs (TAC) for maximum reductions, comparison with GDP.

(a) Short term

country	year	baseline emission (mil.t CO ₂)	Reduction (mil.t CO ₂)	Reduction %	MAC (1) (\$/t CO ₂)	TAC (\$mil.)	AAC (\$/t CO ₂)	GDP (\$bn.)	TAC/GDP
Brazil	2010	767.8	101.3	13.2	25	-1881	-18.6	848	-0.22
Thailand	2010	359.8	99.3	27.6	171	1027	10.3	250	0.41
Zimbabwe	2010	32.7	6.9	21.1	289	221	32.0	35	0.64
Denmark	2005	53.4	11.3	21.2	529	-70	-6.2	154	-0.05
France (2)	2005	407.0	50.9	12.5	-	9725	191.2	1463	0.66
Netherlands	2010	185.0	46.3	25.0	121	1440	31.1	379	0.38

(b) Long term

country	year	baseline emission (mil.t CO ₂)	Reduction (mil.t CO ₂)	Reduction %	MAC (1) (\$/t CO ₂)	TAC (\$mil.)	AAC (\$/t CO ₂)	GDP (\$bn.)	TAC/GDP
Brazil	2025	1611.2	741.2	46.0	29	9339	12.6	1740	0.54
Egypt	2020	253.0	141.7	56.0	2	-732	-5.2	118	-0.62
Senegal	2020	15.4	7.7	50.0	3	-16	-2.0	14	-0.12
Thailand	2030	751.4	221.7	29.5	171	2089	9.4	538	0.39
Venezuela	2025	189.4	50.4	26.6	56	685	13.6	177	0.39
Zimbabwe	2030	57.4	22.2	38.7	289	205	9.3	72	0.28
Denmark	2030	59.3	29.0	48.9	614	168	5.8	211	0.08
France (2)	2030	615.0	153.8	25.0	-	11756	76.5	2400	0.49
Netherlands	2030	204.3	102.2	50.0	78	3775	36.9	548	0.69

¹ The Marginal Abatement Cost (MAC) here corresponds to the level at the maximum reduction achieved for the country.

² The Average Abatement Cost for France is set equal to the rate of carbon tax necessary to achieve the reductions.

Table 4.4.6

Country	CO ₂ reduction option	reduction (%)	MAC (US\$)
Brazil	Electricity savings (industry, services and residential)	7	-66
	Solar uses in agriculture	1	22
	Fuelwood and charcoal for afforestation programmes	21	24
	Ethanol, bagasse and electricity generation from bagasse	19	29
	Total CO ₂ reduction	48	
Egypt	Fuel switching in households	6	-21
	Efficient industrial equipment and maintenance	10	-12
	Transportation	2	-12
	Heat recovery and new industrial processes	9	-8
	New raw materials	5	-3
	Efficient household appliances	5	-3
	Electricity generation	8	-1
	Efficient stoves	7	2
	Total CO ₂ reduction	52	
Senegal	Early hydropower implementation	0.1	-210
	Agriculture intensification	5	-28
	Energy conservation in industry	0.4	-4
	Dissemination of improved stoves	11	0
	Improved carbonisation efficiency	13	1
	LPG-charcoal substitution	15	2
	Biomass from afforestation	6	3
	Total CO ₂ reduction	50	
Thailand	Efficient airconditioners	2	-36
	Electronic ballast	1	-27
	Compact fluorescent lamps (service sector)	6	-14
	Compact fluorescent lamps (residential sector)	2	-9
	Nuclear electricity	18	20
	Highly efficient gasoline cars	1	92
Venezuela	Total CO ₂ reduction	30	
	Reduced flaring and leakage of methane	7	3
	Efficient boilers and kilns	10	10
	Freight transport	1	13
	Efficient electric motors in the industrial sector	2	17
	Passenger transport	4	21
	Electric sector	0.6	35
	Other energy savings in the industrial sector	2	39
	Efficient electric appliances	0.4	52
	Total CO ₂ reduction	27	
Zimbabwe	Efficient boilers	23	-9
	Energy savings in the industrial sector	4	-2
	Efficient motors and power factor correction	2	-2
	Increased hydropower	5	5
	Efficient furnaces	2	66
	Central photovoltaic power	1	153
	Coal for ammonia	1	289
	Total CO ₂ reduction	38	

Table 4.5.1 Global CO₂ Abatement Cost Modelling Studies

Author (year)	Key	CO ₂ reduction from baseline	CO ₂ reduction from reference year ^a	GNP impact/cost (reduction) from baseline
Anderson & Bird (1992)	AB (2050)	68%	-17%	2.8%
Burniaux et al (1991)	B (2020)	37%	17%	1.8%
Burniaux et al (1992)	B (2050)	64%, 64%, 66%	-18%, -18%, -11%	2.1%, 1.0%, 0.3% ^b
Edmonds & Barns (1990)	EB (2025)	14%, 36%, 47%, 70%		0.1%, 0.5%, 0.7%, 2.2% ^c
Edmonds & Barns (1992)	EB (2020, 2050, 2095)	45%, 70%, 88%	22%, 41%, 53%	1.9%, 3.7%, 5.7%
Manne & Richels (1990b)	MR (2100)	75%	-16%	4.0%
Manne (1992)	M (2020, 2050, 2100)	45%, 70%, 88%	13%, 25%, 21%	2.9%, 2.7%, 4.7%
Mintzer (1987)	Mi (2075)	88%	67%	3.0%
Oliveira Martins et al (1992)	OM (2020, 2050)	45%, 70%	-2%, 2%	1.9%, 2.6%
Perroni & Rutherford (1991)	PR (2010)	23%		1.0%
Rutherford (1992)	R (2020, 2050, 2100)	45%, 70%, 88%	15%, 28%, 43%	1.5%, 2.4%, 3.6%
Whalley & Wigle (1990)	WW (2030)	50%		4.4%, 4.4%, 4.2% ^d

^a Negative values imply an increase in CO₂.

^b Toronto-type agreement in all three cases, with tradeable permits in the second and third cases and removal of energy subsidies in the third case

^c Costs as estimated from consumer + producer surplus.

^d The three numbers refer to three different tax forms: a national producer tax, a national consumer tax, and a global tax with per capita redistribution of revenues

Table 4.5.2 Cost Differences for Emission Trading

Numbers refer to a 2 percentage point reduction in emissions from the base line and are global aggregates

		ERM (1)		GREEN		MR	
		Tax (\$/tC)	GDP loss (%)	Tax (\$/tC)	GDP loss (%)	Tax (\$/tC)	Welfare loss (2)
2020	No Trade	283	1.9	149	1.9	325	-
	Trade	238	1.6	106	1.0	308	-
2050	No Trade	680	3.7	230	2.6	448	-
	Trade	498	3.3	182	1.9	374	-
2100	No Trade	1304	5.7	-	-	242	8.0
	Trade	919	5.1	-	-	208	7.5

(1) End-year is 2095 for ERM.

(2) Consumption losses through 2100 – discounted to 1990 at 5 per cent per year – in trillions of 1990 dollars.

*Doesn't supp to be done in chapter 6
Doesn't amount to*

*2 issues: what damage include (in approp place)
• how do approp analyze insurance issue.*

*- thing of us: WTP > EV
not a param. Rich Av. Speed of Response*

MEMORANDUM FOR JOSEPH STIGLITZ

FROM: Ray Squitieri

SUBJECT: IPCC Draft Report Ch. 6, "Decision-making Framework"

*\$ has consensus on carbon, though weight of opinion only limited amt of ins. param sh p'd in mitigation
very though add
top contribute opinion
a take for*

As you may have heard from Sally Kane, I believe that Chapter 6 as currently drafted is seriously flawed. Besides a wide variety of conceptual mistakes, many at odds with the statements in the earlier chapter you had drafted, the text contains entirely inappropriate policy recommendations such as the following:

"Devoting a few percent of world GDP to cutting back carbon dioxide emissions may eminently be justifiable as an insurance policy." (p. 47, line 22)

"The aim hereafter is to address the insurance issue beyond the dedication of a few percent of GDP to cutting back carbon dioxide emissions." (p. 48, line 24)

These statements are not only unsupported by current economic science, but dangerous as well. If they remain in the report, we will be claiming that economists concur that the U.S. should spend \$100 to \$200 billion annually to reduce CO2 emissions. If these statements find their way into the Policymakers' Summary, they will be quoted for the next 5 or 10 years, becoming part of the canons of global warming science, just as conclusions from the IPCC's First Scientific Assessment Report (1990) have become, such as the estimated warming range of 1.5° to 4.5°C. for a doubling of CO2 levels.

The authors' meeting next week represents the best chance to reel chapter 6 back in. I believe that achieving the changes we desire will require your personal intervention, or that of your designee, on both days 1 and 2.

This memo will highlight the most important changes I believe we should seek in Chapter 6.

Inappropriate Policy Conclusions

In several places, the chapter departs from its purpose as an assessment of the state of knowledge, and endorses certain policy positions. These policy positions do not belong in this chapter, whose purpose is to set out the decision making paradigm.

p. 47 "Devoting a few percent of GDP to cutting back carbon

dioxide emissions may eminently be justifiable as an insurance policy."

- p. 48 "Most house owners insure their houses against fire, even though the chances of them being burned are less than one in one thousand.... Climate change ... is a potentially harmful event which is probably much more likely than your house burning down. It may therefore make sense for humanity to insure against harmful climate change. The aim hereafter is to address the insurance issue **beyond the dedication of a few percent of GDP to cutting back carbon dioxide emissions.**"

While the draft should discuss climate change policy as insurance (although I believe options and hedging are a better analogy), it should not call for the spending of "a few percent" -- or any specific amount -- of GDP on reducing CO2 emissions.

Further, the draft's recommendation on this point is exactly contrary to the conclusions of the economic literature to date. Economists who have published results on optimal hedging strategies for climate decisions (Nordhaus, Manne and Richels, Peck and Teisberg) have all concluded that the optimal strategy includes modest mitigation spending in the short run, coupled with increased research to narrow the uncertainties on a few critical scientific questions. If research raises estimated magnitudes or consequences of warming, then mitigation spending should be increased later.

Many prefer to exclude from this scientific assessment any estimates of the appropriate percentage of GDP for greenhouse mitigation. If such estimates are to appear, they should appear in the chapter on integrated assessment, not Chapter 6 on the decision framework. If for some reason it is decided to include these estimates in Chapter 6, then the draft must be amended to contain not just the unreviewed assertions of one writer, but a thorough survey of estimates in the literature (I am familiar with those of Nordhaus, Manne and Richels, and Peck and Teisberg).

Misunderstanding of the concept of insurance

The chapter looks at climate policy as insurance, correctly stating that "Climate change associated risks are difficult to quantify," and that private insurance companies may not be able to insure against climate-related losses. In much of the discussion, however, the draft confuses buying insurance with options and hedging.

When I buy an insurance policy, I pay someone to accept a risk for me. But when the District of Columbia buys a traffic light for the intersection of 17th and Pennsylvania, it is buying a resource allocation device. Climate change mitigation,

research, etc. are more like resource allocation choices than insurance. If global temperatures do indeed rise, then different paths may be taken to avoid consequent damages. Immediate mitigation is one such option. More research on energy conservation is another. Research on likely costs to the economy of different response paths is a third.

In the late 19th century, some Americans became concerned that the U.S. would run out of trees for railroad ties. Did the government buy insurance against this possibility? No. Rather, it established the Forest Service and other agencies to take control over the remaining publicly owned forest land. Instead of saying the government bought insurance against the possibility of a lumber shortage later, it is more accurate to say the government bought an option as part of its hedging strategy. As it turned out, of course, the railroad tie shortage never materialized, but the public forests turned out to have other good uses.

No farmer can now buy an insurance policy against losses from climate change in the year 2050. No insurance company is likely to offer such coverage. Governments may however, decide to spend resources to reduce greenhouse emissions, increase carbon sinks reduce the likely energy requirements of transport, lighting, etc., reduce the likely costs of carbon-free energy sources, or reduce uncertainties about the amount and consequences of warming. In taking these actions, governments are buying options allowing them to lower the total costs they face, given uncertainty about future states of the world.

With time, we will know more about the size of the warming problem, and about optimal response strategies. Spending resources now on further research rather than on increased mitigation is like buying an option that provides the flexibility to delay large resource commitments without sacrificing the ability to act later.

The analogy with insurance leads the draft to incorrect policy conclusions. The draft says that we should decide to spend "a few percent of GDP" on "greenhouse insurance." Then whatever is not spent on mitigation is to be spent instead on research on new supply and conservation technologies, reducing climate and damage uncertainties, etc. (p. 47, line 17). In fact, research is, in this context, a form of option that saves money and social cost in the long run by reducing the need for mitigation spending now.

Hidden assumptions.

Many passages in the chapter implicitly assume that greenhouse mitigation will be cheaper now than later. This assumption is unjustified, for several reasons. First, cheaper mitigation options might become available later; the U.S. economy

uses 30% less energy per unit of GDP than it did 20 years ago; all manner of devices to further reduce fuel consumption are on the drafting boards now. There is no reason to believe this trend won't continue. Second, it might become clear later that climate change is not proceeding rapidly, perhaps because of offsetting factors, or that the consequences of climate change are not very great.

This assumption drives the conclusion that nations should spend "a few percent of GDP" now to reduce greenhouse emissions (actually, the draft repeatedly refers to reducing "carbon dioxide emissions," which is not the low-hanging fruit of a mitigation strategy). Actually, economists and decision scientists know that several strategies may be followed to avoid large damages later. Hedging with options is one way to reduce exposure to risk and thus reduce costs.

Failure to allow contributing authors to review the draft

I do not believe that all principal and contributing authors had the opportunity to review the draft. It does not seem plausible that Kenneth Arrow approved the chapter as it stands, particularly the discussion of insurance and hedging. Moreover, at least two contributing authors, Richard Richels and Stephen Peck, have written extensively on a decision framework for climate decisions, including greenhouse insurance, hedging, and dynamics. The draft quotes their work, but often misses the point of the papers cited. I do not believe that they would have approved a draft containing such fundamental conceptual mistakes, not to mention such gross misrepresentations of their own work. The before this draft goes out again, it must be returned to the authors for their own review.

Recommendation

I recommend that you intervene at the authors' meeting next week, saying that Chapter 6 is unacceptable in its current form because it contains:

- Policy conclusions inappropriate for this chapter;
- Fundamental misunderstandings of several central concepts of decision making on climate change;
- Misquotations of the work of several authors cited, including several contributing authors.

Achieving the necessary changes will require more than line-by-line changes, and probably cannot be done at the meeting. The changes required are too many and too contentious to settle at a large face-to-face meeting.

As I understand the schedule, day 1 will be a plenary session; a strong objection to Chapter 6 should be raised then, for the three reasons listed above. Further, as day 2 will be breakout sessions, chapter by chapter, you may wish to request that a joint meeting be held on the three chapters treating decision making on climate change: your overview chapter, Chapter 6, "Framework for Decision Making," and the chapter on integrated assessment models.

I suggest that you or Sally attend most or all of the discussion of Chapter 6, with the recommendation that 1) the chapter be returned to the contributing authors for review; and 2) the August draft plus the contributors comments be given to several groups for revision. I have attached more detailed comments, which may be useful during these breakout sessions.

cc: A. Munnell
R. Gillingham
J. Hambor
R. Peeler
Sally Kane, CEA



EXECUTIVE OFFICE OF THE PRESIDENT

COUNCIL OF ECONOMIC ADVISERS

WASHINGTON, D.C. 20500

MEMBER

July 29, 1994

Professor Akihiro Amano
School of Business Administration
Kobe University
2 Rokko dai, Nada
Kobe 657, JAPAN

Dear Professor Amano:

You will find enclosed a copy of the first draft of the "Scope of the Assessment" of WGIII which is the responsibility of Writing Team 1 prepared by us with the invaluable help of Sally Kane (of the Council of Economic Advisers).

We regret that the interaction with the rest of the Writing Team 1 has not been as close as we would have liked but we hope to make up for that in the next few months.

All lead authors will be meeting in Geneva, September 8, 9 and 10 which will give us an opportunity for further discussion. We do hope you will attend this important meeting. If needed we can meet again after Geneva.

The Table of Contents which we faxed you last week indicates the thrust given to this Report. The Chapter provides a framework to use to both understand the problem and potential policies (and combinations of policies) that can be used to address the problem. Please note it is not a policy makers' summary; the policy makers' summary will be drafted by the Bureau of WGIII. Moreover, it is not a review of the existing literature on the subject, although we tried to survey most of the available material to well document the discussion. The lack of written material on studies conducted in the developing countries is quite evident and reflects a major weakness of this area of inquiry that has to be remedied in the future. Any suggestions along this line are welcome.

The emphasis given to some of the issues indicates what we think are the key points to be brought to the attention of policy makers and governments, namely:

- a) the all important question of intergenerational equity, intimately related to discount rates (Sec. 1.3.4.1).
- b) intangible costs of warming and nonlinearities and irreversibilities (Sec. 1.3.2 and 1.3.3).

- c) investment and returns to energy saving technology (the bottom-up top-downs controversy) (Sec. 1.6.4).
- d) the all important question of value of the "global commons" through a broader definition of GDP and modifying national accounts (Sec. 1.8.1 and 1.8.3).
- e) the importance of uncertainty, learning, and insurance in selecting the timing and scope of actions taken (Sec. 1.5.3 and 1.5.4).

Finally in Sec 1.9 we tried to summarize "What is Known About Climate Change?" from an economic and social perspective.

We look forward to receiving your comments and criticisms in order to improve the document.

Sincerely,

Jose Goldemberg (Brazil)
Phone: 55-11-2103985
Fax: 55-11-8185031



Joseph E. Stiglitz (USA)
Phone: (202) 395-5036
Fax: (202) 395-6953

Enclosure



EXECUTIVE OFFICE OF THE PRESIDENT

COUNCIL OF ECONOMIC ADVISERS

WASHINGTON, D.C. 20500

MEMBER

July 29, 1994

Dr. Xie Shaoxiong
Senior Engineer
Ministry of Power Industry
137 Fuyou Street
Beijing 100031
People's Republic of China

Dear Dr. Shaoxiong:

You will find enclosed a copy of the first draft of the "Scope of the Assessment" of WGIII which is the responsibility of Writing Team 1 prepared by us with the invaluable help of Sally Kane (of the Council of Economic Advisers).

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Enclosure



EXECUTIVE OFFICE OF THE PRESIDENT

COUNCIL OF ECONOMIC ADVISERS

WASHINGTON, D.C. 20500

MEMBER

July 29, 1994

Mrs. Vijaya Lakshmi (Ruby) Saha
Ministry of Housing, Land, Town
and Country Planning
Edith Cavell Street
Port Louis, Mauritius

Dear Mrs. Saha:

You will find enclosed a copy of the first draft of the "Scope of the Assessment" of WGIII which is the responsibility of Writing Team 1 prepared by us with the invaluable help of Sally Kane (of the Council of Economic Advisers).

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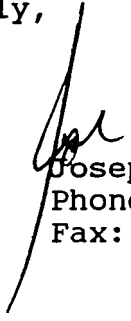
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Joseph E. Stiglitz (USA)
Phone: (202) 395-5036
Fax: (202) 395-6953

Enclosure

From: Sally M. Kane (KANE_S)
To: Stiglitz_J
Date: Friday, July 29, 1994 1:09 pm
Subject: SCOPE mailing: your other intl. authors

We need to send out an interim version to your 3 international co-authors for the SCOPE chapter prior to August 15th. If we waited until the next full iteration was completed, it would be too late for them to review it prior to the 15th.

I would like to send out this interim version that Nate and I are working on THIS MONDAY. All most all of your edits from this week will be included.

Since these people are not economists, I do not think the lack of connection to the general economics literature would be a problem. If we wait, hard feelings could develop, making the meeting in Geneva possibly quite uncomfortable. PLEASE READ AND EDIT THE LETTER JOSE GOLDEMBERG WROTE TO THE INTERNATIONAL CO-AUTHORS.

CC: Branch_L