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International Networks for
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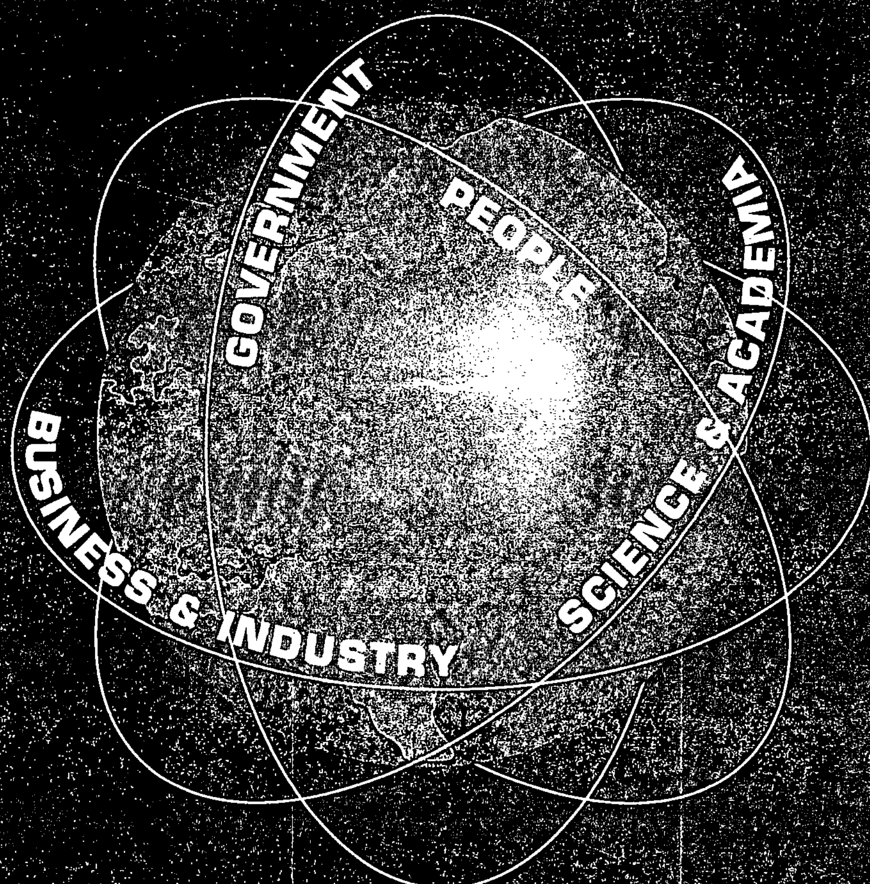
International Networks for Addressing Issues of Global Change



Sigma Xi,
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Research Society

SCOPE PAPER

IPCC

WRITING TEAM 1: SCOPE OF THE ASSESSMENT

1.1 **OVERVIEW.** 4

1.2 **HUMAN ACTIVITY AND GLOBAL WARMING.** 6
- 1.2.0 *Alternative Expressions of Goals.* 6
- 1.2.1 *Effects of Economic Activity on Climate.* 7
  - 1.2.1.1 *Effects of Climate on Economic Activity.* 9
  - 1.2.1.2 *Mitigation Actions.* 9
  - 1.2.1.3 *Adaptation Actions.* 9
- 1.2.2 *Sources of Uncertainty in the Links Between Human Activities and Global Warming.* 9
  - 1.2.2.1 *Uncertainties in atmospheric chemistry.* 10
  - 1.2.2.2 *Uncertainties in general circulation models* 11
  - 1.2.2.3 *Regional and temporal uncertainties* 11
  - 12
  - 1.2.2.5 *Changes in variability.* 13

1.3 **THE COSTS OF GLOBAL WARMING** 15
- 1.3.1 *Tangible Costs of Warming* 15
  - 1.3.1.1 *Sea level rise.* 15
  - 1.3.1.2 *Agricultural production.* 15
  - 1.3.1.4 *Water Resources.* 16
  - 1.3.1.5 *Heating and cooling costs.* 16
- 1.3.2 *Intangible Costs of Warming.* 16
  - 1.3.2.1 *Ecosystem damages.* 17
  - 1.3.2.2 *Species loss.* 17
  - 1.3.2.3 *Amenity values* 17
  - 1.3.2.4 *Human Health.* 17
- 1.3.4 *Nonlinearities and irreversibilities.* 18
- 1.3.5 *Intergenerational Equity.* 18
  - 1.3.5.1 *Discount rate.* 18

1.4 **GENERAL RESPONSES TO GLOBAL WARMING** 20
- 1.4.1 *Adaptation.* 20
- 1.4.2 *Mitigation.* 20
- 1.4.3 *Climate Engineering.* 21
- 1.4.4 *R&D.* 21
- 1.4.5 *Timing of Mitigation.* 21
  - 1.4.5.1 *Joint implementation.* 21
  - 1.4.5.2 *International Trade.* 21
  - 1.4.5.3 *International Agreements.* 22

1.5 **FRAMEWORK FOR POLICY CHOICE** 23

1.5.1 *Introduction.* 23
1.5.1.1 *Goals of the Rio Convention -- Thresholds.* 23
1.5.2 *Paradigms of Choice.* 23
1.5.2.1 *Standard Cost-Benefit Analysis Paradigm.* 23
1.5.1.2 *Dynamic Optimization Paradigm (Ramsey Model)* 24
1.5.1.3 *Decision Theory Paradigm.* 25
1.5.1.3.1 *Learning.* 25
1.5.1.3.2 *Risk Aversion.* 25
1.5.1.3.3 *Weakness--Analytical and Computational Complexity.* 26
. . . . 26
1.5.2.1 *No Regrets Policies.* 26
1.5.2.2 Importance of Flexibility in Timing. 27
1.5.2.3 Insurance and hedging. 27
1.5.2.4 Carbon Taxes and Uncertainty. 27
1.5.2.5 Control Policies Under Uncertainty. 28
1.5.2.6 Timing of Critical Policy Decisions. 28
1.5.2.7 Mid-Course Corrections. 28
1.5.2.8 Irreversibilities. 28
1.5.2.9 Value of information. 28
1.5.2.10 Portfolio of responses. 29
1.5.2.11 Sequential dynamic decision making. 29
1.6 ECONOMICS OF POLICY ACTIONS . . . . ,30
1.6.1 ***The Ultimate Objective and Its Relationship to Intermediate Aims.***
. . . . 30
1.6.1.1 *Possible conflicts between intermediate and ultimate objectives.*
. . . . 30
1.6.1.2 *Possible synergies between intermediate and ultimate objectives.* 30
1.6.1.3 *The ultimate objective and "room" for future emissions growth.* 31
1.6.2 ***The Economics of Energy-Using Technology.*** 31
1.6.2.1 *Factors Influencing the Adoption of Technology* 31
1.6.2.2 *Impact of factors affecting adoption of technology.* 32
1.6.2.3 *Opportunities for greater energy efficiency* 32
1.6.2.3.1 *More efficient technology* 33
1.6.2.3.2. Low-emission energy sources. 34
1.6.3 ***Carbon Taxes and Related Policies.*** 34
1.6.3.1 *Carbon taxes* 34
1.6.4 ***Market Structure Reform.*** 35
1.6.4.1 *Market reforms that also reduce greenhouse gas emissions.* . . . 35
1.6.4.2 *Policies to Induce Innovation* 36

1.7 NATIONAL ACTION PLANS 37

1.8 SUSTAINABLE DEVELOPMENT 38
1.8.1 *What is sustainable development?* 38
1.8.2 *The Need for a Broader Definition of GDP* 38
1.8.3 *Modifying National Accounts* 39
1.8.4 *Implications of sustainable development for developing countries* 39
1.8.5 *Sustainable development and the risks of climate change* 40
1.8.5.1 *Population change* 40
1.8.5.2 *Energy use* 40
1.8.5.3 *Deforestation.* 41
1.8.5.4 *Poverty* 41

1.9 WHAT IS KNOWN ABOUT CLIMATE CHANGE? 42

1.10 REFERENCES 44

1.1 OVERVIEW.

The natural science community has concluded that increased greenhouse gas concentrations in the atmosphere could lead to significant changes in the climate system, at a rate greater than any experienced over the past several hundred years (IPCC 1992). Recent findings from climate models reinforce this conclusion. And at rates of climate change projected by general circulation models, significant changes to physical and social systems could occur. Therefore the risks posed by an enhanced greenhouse effect are potentially large.

The IPCC has identified economic and social forces as important drivers in climate change:

> "Population and economic growth, structural changes in economies, energy prices, technological advance, fossil fuel supplies, nuclear and renewable energy availability are among the factors which could exert major influence on future levels of CO2 emissions." (IPCC 1992, p. 17).

This Second Assessment report will thus address the question of what is known about the effect of social and economic forces on climate change, and about the effect of future climate change on social and economic indicators.

Good estimates of the net costs of climate change exist for developed countries, but not for developing countries, and not for countries isolated from international markets. Neither regional effects of climate change nor effects of the timing of climate change have been well studies. Therefore, although existing studies calculate small average costs from warming, the effects on some countries and regions could be much larger.

In evaluating the risks posed by an enhanced greenhouse effect, the timing of responses in the climate and human systems is critical. If the climate system changes have a long lag prior to their manifestation and quick social response is feasible, then the risks faced are minimal. However, short term response in the human system is inherently difficult; without new government incentives, inducing adoption of new efficient energy producing technologies, replacing the current transportation system dependent on fossil fuels with one that uses cleaner fuels exclusively, and changing land-use patterns in agriculture and forestry takes a long time, in some cases decades.

With uncertain but possible large risks and long lead times required for behavioral response, investments in measures that could provide safeguards become more desirable. Two general types of measures can provide safeguards: mitigation and adaptation. In the first case, mitigation strategies reducing the rate at which greenhouse gases are being emitted into the atmosphere serve to delay or prevent climate changes. Examples of mitigation strategies are market improvements (such as removal of energy subsidies) that also reduce gases and government improvements that remove disincentives for efficient investments. In the second case, adaptation strategies serve to enhance societies ability to withstand changes in sea levels, flooding, and crop growth conditions and in some cases capitalize on positive opportunities.

This chapter provides a framework for thinking about global environmental problems in general, and climate change in particular. Building on the detailed information provided by the first two parts of this Second Assessment, important relationships are highlighted to provide guidance for understanding choices and tradeoffs that will be made in responding to climate change.

Induced climate change is a global problem. The atmosphere is a shared resource and receptor of pollutants from everyone. Conversely, the pattern of altered climate conditions resulting from climate change are broad, truly on a global scale. The stakeholders in the problem span the globe: they include countries for whom control of gases on a per unit basis is expensive and countries that might suffer the greatest hardships in adapting to changes. Significant reduction of greenhouse gases at lowest costs possible (that is costs of effects plus policies undertaken) will require coordination at a regional and global level, recognizing that each country has unique circumstances and outlook that will determine its choice of policies.

1.2 HUMAN ACTIVITY AND GLOBAL WARMING.

For centuries, humans have altered the local climate, both intentionally (such as by cloud seeding) or unintentionally (through land clearing for agriculture that change local hydrologic regimes and through urbanization creating heat islands). In recent years, climate scientists have become increasingly concerned that human activities may alter the global climate as well through emissions of greenhouse gases into the atmosphere.

1.2.0 *Alternative Expressions of Goals.*

The effects of changes in the climate system on human society's are uncertain, but are possibly large depending on the timing and the rate of change incurred. Human societies change over time, only partially in response to fluctuations in environmental conditions. Examination of effects (both benefits and costs) of climate change take place in the context of the dynamics of social change.

National and international approaches being undertaken (or suggested) to respond to the threat of climate change vary widely around the world. Approaches being discussed emanate from the circumstances particular to countries/regions including cultural traditions, natural resource base, political and economic structure, and population size and growth rate. For example, two countries similar in size and natural resource endowments may consider different types responses because of differences in cultural goals and differences in political systems. [Japan vs. Germany --example ??]

Alternate goals of human societies directly influence policy choice among countries/regions. While the goals are not mutually exclusive, there are often trade-offs. One universal goal is the desire on the part of each country/region to provide an improved standard of living for its citizens. All citizens need ready access to potable water, food, housing, education, and health care to be productive members of society. Economic growth lead to an improved standard of living as long as political and economic institutions are stable and conducive to these changes. Without continued economic growth, investments to reduce emissions could result in a slow-down or reduction in the standard of living, a trade-off developing countries would find difficult.

Sustainable use of resources, better known as sustainable development, is another goal of societies. One prevalent definition of sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). This goal implicitly considers the well-being of future generations as equal to that of the present generation.

A more ambitious goal is that of environmental equity. Equity considerations involve comparison of environmental effects both in time and space. For example, geographic equity could be advanced to populations with less income and less ability to mitigate/relocate away from adverse environmental conditions. These poorer populations could qualify for compensation to help absorb the adverse effects of climate change. A side issue of this goal is the question of whether the basis for decisions rests on a human-centered principles or environment-centered principles. Western tradition uses a human-centered paradigm, where adversely effected environment (either species or ecosystems) are considered only in its relation to human welfare. An environmental-centered paradigm treats the environment as having intrinsic value in itself, leaving open the possible trade-off between human welfare increases and perpetuation of a fragile ecosystem.

1.2.1 *Effects of Economic Activity on Climate.*

Carbon dioxide is emitted from fossil fuel combustion, combustion of cleared biomass stocks, the decay of surface or soil biomass in disrupted ecosystems (e.g. wetlands) and subsequent management of soils, and from carbonate rock during the manufacture of cement. Methane is emitted by ruminant animals the principal stocks of which are maintained to produce meat, dairy products, and animal power; from rice paddies; from fossil fuel production where some natural gas (methane) is lost through leaks during mining and transportation and gas associated with oil and coal deposits is vented; from incomplete combustion of biomass largely during open burning of cleared areas or of agricultural wastes; through wetlands; and through leaks of methane generated through anaerobic decomposition of waste in landfills. Nitrous oxides are a product of combustion and are released from soils as part of the nitrification process. Disruption of soils (land clearing) may lead to denitrification and application of nitrogen fertilizer increases the amount of nitrogen available that can be emitted as nitrogen oxide (IPCC 1990).

> Human activities, primarily energy and agriculture, are increasing atmospheric concentrations of greenhouse gases. All theoretical models predict that changes in greenhouse gas concentrations will cause changes in climate both regionally and globally. While significant uncertainties remain, current predictions suggest that the rate of climate change will far exceed any natural changes seen over the last 10,000 years, with potential adverse consequences for managed and natural ecological systems.
>
> The increase in global temperature (0.3 to 0.6 degree Celsius) that has occurred over the last 1000 years cannot be definitively ascribed to the greenhouse effect. It may primarily reflect natural variability, or it may reflect a combination of natural variability and other human-induced changes in climate that are partially offsetting the full greenhouse effect. If an enhanced greenhouse effect does occur, it could not be naturally reversed to many decades or centuries, because of the long atmospheric lifetime of the greenhouse gases and the thermal inertia of the climate system.
>
> Box 1: The Scientific Consensus on Greenhouse Warming

Chlorofluorocarbons are used as coolants in refrigeration and air conditioning and as propellants. They are radiatively active in the troposphere but destroy radiatively active ozone in the stratosphere. They may or may not be net greenhouse gases (IPCC 1992), but their presence has implications for the vertical and longitudinal temperature gradient. This may affect cloud formation and storm tracks **(cite)**. Carbon monoxide, Total greenhouse gas emissions may be broken into components as follows (Kaya 1989):

Emissions = emissions/unit energy x energy/gdp x gdp

Or in terms of growth rates:

growth (em) = growth (em/en) + growth (en/g) + growth (g)

where

growth (a) = growth rate of factor a
em = emissions level
en = energy consumption
g = gdp

Using world aggregates for 1971 to 1988 gives

1.9%/yr = -0.5% -0.8% +3.2%

Thus, economic growth has increased greenhouse gas emissions at the same time that falling ratios of energy to gnp emissions per unit energy have reduced emissions. The energy/gnp ratio fell with post-1973 adjustments to higher energy prices, coupled with the long-term secular trend away from energy-intensive materials. The shift away from coal has lowered emissions per unit energy. In a growing economy with advancing technology, right-hand terms 1 and 2 would ordinarily be negative, and term 3 positive.

Box 1: The Components of Greenhouse Emissions

emitted from combustion of fossil fuels and biomass, while not radiatively active itself, is a determinant of the rate of decay of methane (IPCC 1990).

Particulate emissions also affect climate. While extremely short-lived (atmospheric residence time measured in days), the cooling effect of current levels of sulfate particulates, largely from coal burning, may have offset much of warming in the northern hemisphere during the last several decades (IPCC 1992). This cooling effect may explain why climate models have consistently overpredicted temperature changes actually observed.

Land use changes also affect climate. Deforestation adds to net greenhouse gas concentrations: directly, by releasing soil carbon and by burning; indirectly, by reducing the stock of carbon sinks. On the other hand, a global forestation effort might decrease albedo (reflectivity) and thus lead to warming that would substantially offset the carbon reduction value of the forestation program **(cite)**. Changes in forest cover, irrigation, and similar changes may also have implications for the hydrological cycle. Atmospheric carbon and nitrogen deposition likely enhances plant growth and hence increases carbon stocks. Other pollutants (such as ground-level ozone) have negative effects on plant growth; some are chemically reactive in the formation or destruction of radiative gases (IPCC 1992).

The relative contribution of human activity compared with natural sources of climate change can be measured in different ways. The greenhouse effect (radiative trapping of heat) is a natural phenomenon amplified by human activity. The "natural" greenhouse effect due to water vapor and preindustrial levels of carbon dioxide raises the earth's temperature by about 30° C from an average of -15 C to +15 C (-5 F to 60 F) (Albritton, 1992). A projected increase in temperature of 3° C by 2100 would thus mean a 10 percent change in the greenhouse effect.

1.2.1.1 *Effects of Climate on Economic Activity.*

A warmer climate would directly affect the temperature-sensitive sectors of the economy: agriculture, forests, and fisheries; and construction. Because of the risk of drought, arid and semi-arid regions are likely to be most vulnerable to warming. A warmer climate may also encourage insect populations, which is likely to decrease agricultural yields in some regions. On the other hand, increased CO2 concentrations increase photosynthesis and the effect of water consumption in controlled settings, and may do so in farmers' fields.

A warmer climate may affect other sectors indirectly, through increased demands on water resources, and a possible increase in air pollution if energy consumption increases as a result. In addition, increasing storms that may result from a warmer climate would affect coastal areas including low-lying island states. Social effects of climate change can not be translated easily from changes in the physical systems. In the forestry and agricultural sectors, world markets would moderate the effects felt by individual countries or regions. Full effects are influenced by type of economy, participation in international trade, world pattern of changes in physical conditions, and flexibility in the economic systems to change as conditions change. Full effects in countries with less developed economies and economies in transition are less well understood. The range of effects are described in greater detail in sections 1.3.1 and 1.3.2.

1.2.1.2 *Mitigation Actions.*

Mitigation actions are targeted to reduce greenhouse gas emissions and if restrictive measure are taken concentrations in the atmosphere could ultimately be reduced. Actions include reducing fuel consumption, switching to less carbon-intensive fuels, and reducing emissions of methane and other greenhouse gases. Given the limited understanding of the climate system, mitigation provides the surest measure for avoiding the consequences of climate change; but mitigation alternatives present economic, environmental, and health and safety consequences of their own. Alternative sources of energy (nuclear, solar, wind, biomass, geothermal) generate radioactive waste, toxics, and may affect fragile ecosystems and the lands of indigenous people (cite).

1.2.1.3 *Adaptation Actions.*
Adaptation actions serve to lessen adverse effects or use opportunities created by an altered climate. Social systems evolve over time and naturally respond to changes in circumstances, whether they be economic, political, social, legal, etc. Enhanced adaptation can be facilitated through government actions. Government investment in R&D could be made to intensify development of new varieties of crops that can withstand significant changes in growing conditions. Populations of people could be moved to relatively less vulnerable areas. Investments in sea walls and changed specifications of facilities located along the coast would augment protection of low-lying coastal areas.

1.2.2 ***Sources of Uncertainty in the Links Between Human Activities and Global Warming.*** **(to be re-written by climate specialist)**
Atmospheric scientists are uncertain about how changes in today's emissions of various greenhouse gases will affect future atmospheric stocks of these gases and thus future radiative forcing (heat trapping ability). Scientists are also uncertain about how changes in radiative forcing will affect future climates. Major questions remain about the carbon cycle and therefore about the uptake of carbon in the ocean and in forests in the northern hemisphere.

Most international environmental agreements are made amid continuing scientific uncertainty; this will be particularly true of agreements on climate change. While scientists agree that greenhouse gas concentrations are increasing, they do not agree about the mechanism linking concentrations, temperature, and well-being. Thus, although scientists agree that some warming will occur, they do not agree on the speed of change, or the ultimate amount of change (IPCC 1992). Important areas of uncertainty include the following: 1) How changes in today's emissions will affect future concentrations of greenhouse gases; 2) How changes in the time path of radiative forcing would affect future climate; and 3) How changes in future climates would affect human welfare.

Feedback loops complicate the analysis even further. Negative feedback loops in the atmosphere may offset much or all warming that would otherwise occur. For example, warming leads to greater evaporation, more clouds, more reflectivity, and thus less warming; also, increasing CO_2 may increase carbon sequestration through faster plant growth. On the other hand, positive feedback loops may accelerate warming: warmer oceans would likely absorb less CO_2.

1.2.2.1 *Uncertainties in atmospheric chemistry.* **(review needed by atmospheric chemist, Albritton ?)**
It is not known how today's greenhouse emissions will affect tomorrow's atmospheric concentrations. The major greenhouse gases remain in the atmosphere for a long time: except for methane, generally more than 100 years. Greenhouse gases accumulate slowly, but persist for a long time (IPCC 1990). Although fossil records show a close

relationship emissions of carbon from fossil fuels and atmospheric stocks of carbon, scientists are unable to account for about 40% of the carbon released from fossil fuels and biomass (Schlesinger 1991; Albritton and Levy, 1993). This inability to account for carbon leads to uncertainty with regard to the future rate of uptake of carbon from the atmosphere.

Scientists do not yet know whether chlorofluorocarbons, on balance, add to radiative forcing or not, because the direct effect of radiative forcing is offset by an indirect cooling effect of stratospheric ozone depletion (IPCC 1992). Far greater uncertainties exist with regard to other trace gases because known sources and processes of elimination do not explain recent rates of increase in the atmosphere. Recently attention has shifted to the cooling effect of sulfate aerosols, the role of carbon monoxide in the methane cycle, interactions of changes in climate with atmospheric chemistry (most chemical reactions are heat dependent), and terrestrial responses to climate change such as the release of methane from permafrost (IPCC 1992).

Scientists do not agree on how to measure the warming potential of different greenhouse gases (IPCC 1992). Although global warming potential (GWP), endorsed by the IPCC, is a useful concept in formulating comprehensive approaches to greenhouse abatement policies (Stewart and Wiener 1990), some analysts have recently criticized the concept on the grounds that GWP implicitly sets the opportunity costs of an increment in radiative forcing equal for all periods in the future (Eckaus 1992, Schmalensee 1993). Actually, these opportunity costs are not constant, but vary over time; hence emissions reductions will impose different costs at different times. Finding an optimal path for greenhouse emissions requires comparisons of the discounted marginal damages of emissions from different gases. But GWP, the index most often used to compare greenhouse gases, is not based on such a damage comparison.

Insert table on GWP potential here

Table 1: Global Warming Potential–Relative Contribution to Global Warming

1.2.2.2 *Uncertainties in general circulation models* **(review and edits by climate modeler)**
Even if future atmospheric concentrations were known, scientists could not yet confidently predict future climates. The major climate models do show modest agreement on the magnitude of the effect of a doubling of greenhouse gas concentrations on equilibrium global average temperature, with the range of estimates of temperature increases generally between 1.5 and 4.5° C; associated precipitation increases range from 7 to 15 percent (IPCC 1992).

1.2.2.3 *Regional and temporal uncertainties.*

Uncertainties about the timing of effects, critical in evaluating the potential for human adaptation, require improved understanding of the transient path of climate change. Research is continuing on the inertia effect of the ocean which acts as a heat sink, delaying the realization of the full effect for many years. Failure to include realistic linkage with ocean models is one reason that the major models have so far generally overpredicted the climatic effects of trace gas accumulation (**cite**).

The socio-economic impacts of climate change are influenced strongly by localized climatic factors. Moreover, on a regional scale, direct and indirect effects influence human systems and unmanaged ecosystems. For example, warming may change actual level of the oceans (often deviating from mean sea levels), may change frequency, duration, and tracks of storms along the coast, may change inland conditions leading to changed pollution patterns along the coast, and may change features of agricultural systems along the coast through soil moisture and change in pest cycles. Regional fisheries could also be affected, by both human fishing policies and changes in natural conditions.

A short list of regional changes can be made. Sea level is expected to rise about 50 centimeters over the next century (**need latest figures**) for a 3 degree C temperature increase. Much work is on-going to translate these figures for individual regions around the world. Terrestrial effects can be described broadly. In general, climate models predict reduced soil moisture in mid-latitude continental areas, increased precipitation in high latitudes, and greater warming toward the poles.

The short list of accepted conclusions about regional effects makes it difficult to predict social and economic effects of rising CO2 concentrations. Probabilistic analyses of emissions of carbon dioxide (Nordhaus and Yohe **date**, Reilly, et al.. **date**, Manne and Richels **date, non-US citations will be added**) have been undertaken by several researchers. Integrated analysis that can evaluate these probabilistic scenarios in the context of atmospheric chemistry, climate, effects, and policy models is developing (**OECD, US citations**).

1.2.2.4 *Uncertainties in policy responses.*
Uncertainties concerning policy responses center about 4 questions:

1) Do the behavioral assumptions of policy models reflect actual behavior of the parties involved?

Behavioral assumptions vary from one type of policy model to another. Economic optimizing models (**... 1-sentence description**). They assume that consumers and producers maximize profits or utility within some constraints. But optimizing models omit many of the critical features of real-life decisions, including the costs of information, and the difficulty of fully rational decision making (**cite late 1970s survey of energy models, or EMF**). Econometric models **description ...** In contrast to economic optimizing models, econometric models better reflect actual observed behavior, although at some cost in consistency of specification (cite). Engineering cost models ... **description ...** They rarely account for subtle qualitative differences in the services delivered from energy conserving technologies, and implicitly assume that the information and behavioral barriers can be costlessly overcome (cite). These differences generate widely different estimates of the costs of meeting specific targets (EMF-12, OECD).

2) Will the policies actually adopted--as distinct from those considered in the analysis--be effective?

Policy analysts make simplifying assumptions in order to make their formulations computationally feasible, and consistent with current theory. For various reasons (Cyert and March 1963, Simon 1957), governments often violate the assumptions adopted by analysts.

3) Can an agreement be reached that leads to effective action among the parties?

Political scientists have found that achieving agreement on an effective low-cost policy is difficult (cite). The negotiation process alone, for example, involves establishing new property rights and claims over the absorptive capacity of the atmosphere, while at the same time negotiating the level of control.

Compensation agreements will not be easily reached (cite). Because it is difficult to predict what climate would have been had the stock of trace gases not been altered, it will be difficult to attribute particular climate events to parties responsible for altering the climate. Droughts, floods, and hurricanes are features of a normal climate. How much worse or how more frequent such events are because of human alteration of the atmosphere will be difficult to determine (cite). Further, compensation depends on defining new property rights, a difficult goal.

Adaptive responses are easier to predict because they are regionally based (cite). Nations and most other agents gain all the benefits of adaptive action, and suffer all the losses of failing to adapt. Adaptive responses depend, however, on regional predictions of climate change, and these are notoriously difficult. Timing of responses is important in relation to the speed of climate changes. If the lag in societal response is short relative to the change in climate effects, adaptive strategies (such as crop switching) are viable, and scientific uncertainties are relatively unimportant. If, however, response lags are long (such as construction time for new nuclear power plants), then scientific uncertainties gain importance.

4) To what extent can agreements be enforced, maintained, and updated as new information becomes available?

Countries will sign agreements for international cooperation when the gains from acting together exceed the gains from acting alone. In this respect, international environmental agreements are like producer cartels (Barrett, **date**). But just like cartels, international environmental agreements will collapse if cooperation demands large sacrifices from the cartel's members. More than any international agreement reached to date, new scientific findings will for many decades require significant modifications to agreements likely to be in place.

1.2.2.5 Importance of extreme events

Many of the costs of climate change are likely to stem from extreme climatic events: extra days of extreme heat or drought, increased severity of storms, etc. Conversely, some of the benefits will also stem from a reduction in extreme events: e.g. fewer days of frost in some cold regions. Further, many of the measurable effects of climate change will appear in years in which climate extremes would have prevailed even without an underlying warming trend. For example, agricultural yield studies show that warming would lead to only minor crop losses in a normal year but large losses in an otherwise hot and dry year; thus a warmer climate could turn a marginal year into a disaster (**check and cite**). Similarly, 90 percent of soil loss due to erosion occurs during 1 or 2 major storms each year, and almost all coastal property losses occur as a result of extreme storms (**cite**). In general, more extreme weather leads to disproportionately greater damages. By the same token, a warmer winter climate can disproportionately reduce the damages caused by extremes of cold.

Because of the importance of extreme events, an appropriate behavioral model often focuses on changes in the mean likelihood of an extreme event, or a change in the mean expected loss due to an extreme event (**cite**).

1.2.2.5 *Changes in variability.*

A changing climate may also change the variability of the climate; climatologists have no firm evidence, however, as to whether climate will become more or less variable daily and seasonally. Realistic climate scenarios coupled with impact models that effectively treat climate will be necessary to evaluate the implications of changes in variability. For example, if the real limits to crop production are frosts and days of extreme heat, then models that incorporate only monthly mean temperature will be unable to distinguish between a climate with strong diurnal variation and hence more frequent frosts and very hot days, from a climate with a weak diurnal pattern. Whether and when climate models will be able to shed light on these detailed patterns of change is unclear. The inability to do so leaves us with substantial uncertainty in existing analyses (**cite**).

The normal variability of existing climate also makes it difficult to detect any warming that might be occurring. The "signal to noise" problem makes it possible for observers to mistakenly consider a normal extreme event as evidence of a trend, or to fail to see a trend in a noisy data series. Because of the signal-to-noise problem, the scientific community is unable to indicate confidently whether extremely warm years of the 1980's are evidence of climate change or not.

Suppose curve A is the temperature distribution during an average growing season, and curve B is the distribution after significant warming. Significant crop damage occurs beyond temperature T*. Area a gives the total heat-related damage in an average growing season; area b gives total heat-related damage after significant warming has occurred. If damages depend on weather extremes, then even a moderate increase in average temperature can have a much larger effect on crop losses.

The Disproportionate Effect of Extreme Values on Total Damages

1.3 THE COSTS OF GLOBAL WARMING

A changing climate imposes costs both tangible and intangible. In the developed world, the impacts are likely to be felt largely in agriculture and other climate-sensitive sectors of the economy. For most developed economies, these sectors constitute a small share of the total (cite). For developing countries, the impacts will be more widely felt; first, because agriculture is a larger share of the economy; and second, because climate change can disturb an otherwise orderly development plan, diverting capital that would have been available for other more productive uses. Mitigation and adaptation may also claim resources from necessary consumption.

1.3.1 *Tangible Costs of Warming*

1.3.1.1 *Sea level rise.*

Mean sea level has risen 10 to 20 cm over the past century, mostly the result of thermal expansion of the oceans. The IPCC projects mean sea level to rise 27 to 71 cm by 2070 (IPCC 1990). Tangible effects could include inundation of wetlands and lowlands, faster coastal erosion, more coastal flooding, and increased salinity of bays and aquifers (Titus 1992). Glaciologists have now largely dismissed earlier fears that a doubling of CO_2 could cause the West Antarctic Ice Sheet to break off and slide into the ocean, dramatically raising sea level (cite).

1.3.1.2 *Agricultural production.* (re-writing needed)

A warmer climate would hurt agriculture in some regions but help in others. With warming expected to be more pronounced in the higher latitudes, agriculture would improve in Canada, Northern Europe, and the former Soviet Union (IPCC 1990). Further, most models predict that warming would most effect nighttime and wintertime temperatures. This would increase crop yield (cite--Science?/Cl 101). On the other hand, the same warming, with accompanying drying of continental interiors, would decrease production in western Europe and the U.S. (cite). There, heat stress and decreased soil moisture would reduce crop yields. Corn yields in the U.S. Great Lakes area, for example, may decline significantly as higher temperatures accelerate plant growth, allowing less time for development before maturity (Ritchie et al. 1989). Coastal inundation of some rice growing regions of Southeast Asia, such as Bangladesh, would decrease yields there. On balance, most analysts expect that worldwide agriculture will suffer only modestly, if at all, in part because of crop shifting and other adaptation by farmers and the moderating influence of trade in international agricultural commodity markets (Ausubel 1990; IPCC 1990).

1.3.1.3 *Forests.*

A warmer climate implies both northward movement of forests and changes in forest composition. The result would be to reduce boreal forests and, by a smaller percentage, to increase tropical forests. On balance, doubling CO_2 concentrations would modestly reduce both standing biomass and forest area (Sedjo and Solomon, 1989). Some analysts also calculate an additional temporary decline in forest cover during the transition to a warmer climate (EPA 1989); this decline could last for several hundred years, as more forest death occurs on southern edges than additional growth occurs on northern edges. Higher CO_2 concentrations might increase tree growth, partially offsetting direct losses from warming (**cite**).

Warming will likely increase forest growth in boreal and temperate forests and decrease growth in tropical forests. Thus, while in agriculture warming favors cold climates, (including most OECD countries) at the expense warm climates (including most LDCs), in forestry, warming favors warm climates (mostly LDCs) at the expense of cold climates.

1.3.1.4 *Water Resources.*

Some analysts conclude that a warmer climate would significantly reduce water supply (Gleick 1987). If a warmer climate changes the precipitation balance toward more rain and less snow, the result will be earlier and greater runoff in spring and summer. For some regions, floods will increase yet available water will decrease. Most climate models now predict hotter and drier weather for the mid continents (IPCC 1990). If this occurs, the downward pressures on water supply will be intensified by upward pressures on water demand.

Because of the key role of local conditions, further generalizations are difficult. River basin runoff is the difference between precipitation and evaporation plus absorption (IPCC 1990). Hence small variations in these three terms--each of which depends on the accuracy of regional climate forecasts--can make a large difference in the runoff.

A rising sea level would also inundate some small island nations, flood some low-lying coastal cities (e.g. in Bangladesh), damage coastal farmland, and contaminate water supplies (IPCC 1990).

1.3.1.5 *Heating and cooling costs.*

A warmer climate implies reduced heating costs and greater cooling costs. At least for countries in temperate and cool climates, this would move the population-weighted average temperature closer to the ideal indoor temperature. All else being equal, heating and cooling costs, considered together, should decline. Complicating the calculation however is the thermodynamic reality that more energy is typically required to cool a room by 1 degree than to heat it by 1 degree. While electricity, with its associated conversion losses, powers air conditioners and fans, most heaters burn fuel directly, in both developed and developing countries; electricity generation losses mean that primary energy requirements for cooling may exceed those for heating even for climates in which the mean outdoor temperature lies below the ideal indoor temperature (EPA 1989).

An earlier study of space heating costs by the IPCC finds net energy and economic savings for Germany and the former Soviet Union, but net energy and economic costs increase for the United States. Considerable uncertainty continues to surround these estimates.

1.3.2 *Intangible Costs of Warming.*

Intangible costs may include a loss of biodiversity, deforestation leading to soil erosion and enhanced surface runoff, water pollution, and soil degradation. These costs are social costs not adequately considered in the pricing mechanisms. Current valuation techniques are crude. Some analysts, have found tangible costs to be small, and believe that the justification for costly, and more, restrictive actions rests on intangible costs (Nordhaus, **date**), which remain poorly understood.

1.3.2.1 *Ecosystem damages.*

Population pressures have added to pressure on ecosystems, particularly in the third world. Climate change may exacerbate these damages, particularly in Africa, where environmental degradation has been particularly pronounced during the last 15 years (UN, 1989). During that time, arable land per person fell from 0.5 ha in 1965 to 0.3 ha in 1987, as overuse cut into soil fertility, and demand for land resulted in semi-arid land and other marginal cropland being pressed into service (World Bank 1992). Already more than one-third of Africa is under the threat of desertification, mostly from mismanagement of land, and the overcutting of brushwood for fuel, rather than drought. If climate change increases the length and severity of droughts, however, desertification would be accelerated.

1.3.2.2 *Species loss.*

Human activity has already accelerated the natural process of species loss (EPA 1989). A warmer climate, with consequent northward movement of forests, is expected to hasten this trend. Rapid deforestation also accelerates species loss. Within Africa for example, deforestation is proceeding 30 times faster than reforestation, mainly as land is lost to agriculture. Shifting climate will in some areas make this problem worse.

Economists have just begun to measure the value of biodiversity and hence the value of preserving different species (Weitzman, Solow, et al. 1993?). Much testing and application must precede useful application of these methods.

1.3.2.3 *Amenity values.*

A warmer climate would improve human comfort in cold areas, and in the winter generally, while decreasing comfort in warm areas. Mearns et al (1984) calculate a threefold increase in heat waves for a 1.7 degree C. rise in U.S. mean temperature. The question for policy analysts is, will net comfort rise or fall for a given rise in temperature? Schelling (**cite**) notes that people generally move toward warmer climates, and concludes that a warming would increase rather than decrease human comfort.

1.3.2.4 *Human Health.*

A warmer climate is expected to increase summertime deaths from heart disease, stroke, etc., and decrease wintertime deaths from pneumonia, etc. One study calculates excess deaths resulting from a warmer climate in 15 major U.S. cities (Kalkstein 1989). Using these results, EPA (1989) finds that excess summer deaths would significantly exceed reduced winter deaths, and thus attributes a significant net cost to a warmer climate. Others, however, have concluded that no strong evidence exists for attributing excess deaths to higher temperatures (Cline 1992).

1.3.3 *Adaptation.*

(text will be added about two types of adaptation: natural adaptation of social systems and enhanced adaptation encouraged through government policies)

1.3.4 *Nonlinearities and irreversibilities.*

Beyond these nonlinear effects, however, climatologists note the possibility of some very severe effects or extreme nonlinearities **(cite)**. If, for example, the deep-water conveyer current in the North Atlantic were very sensitive to additional fresh-water runoff, as has been suggested, then even a modest change in temperature could, by changing the conveyor, dramatically alter the Earth's climate. Other catastrophic events could include the release of methane from permafrost warming, or the breaking up of the West Antarctic Ice Shelf. Recent evidence from the Greenland ice cores hints that the Earth's climate has experienced changes of several degrees over just a few decades several times in the last 100,000 **\check** years (ref. <u>Science</u>?).

Many damage effects rise nonlinearly with temperature changes. Thus, one study estimates that a doubling of sea level rise would imply a tripling of the resulting economic damages for the U.S. (Yohe 1992). Some evidence suggests, though not conclusively, that warming would increase the severity and frequency of tropical storms (IPCC 1990).

While the costs of warming as generally calculated--both tangible and intangible-- fit neatly into the familiar cost/benefit framework, catastrophic change and irreversibilities would alter all existing relationships and necessitate major restructuring of the problem. Catastrophic change reduces the time available for response changing the calculus of benefits of action now versus action later. Similarly, irreversibilities in adverse effects forecloses opportunities for adaptive strategies adding weight to mitigation approaches. Whether catastrophic changes occur will depend in large measure on response times in the physical and social systems.

1.3.5 *Intergenerational Equity.*

Climate policy raises particular questions of equity between generations, because future generations are not able to influence directly the policies being chosen today that will affect their well-being. Because climate change policy involves trading off near term costs (e.g., of emission controls) for long-term benefits of a reduced rate of warming, choice of a discount rate is crucial for rational policy making.

This debate is driven by alternative views of the intergenerational equity of discounting distant future benefits (Ramsey 1928, Mishan 1975, Sen 1982), by the question of whether investment not made to reduce greenhouse emissions (because the rate of return is inadequate) would in fact be made in the general economy where real returns are higher. A second consideration is that future generations may have a right to enjoy resources at least as great as those enjoyed by today's generation (Brown-Weiss 1989).

1.3.5.1 *Discount rate.*

Productive investments yield a positive real return, both in physical capital (e.g. machines) and human capital (e.g. education). That is, money productively invested today can be transformed into more money later, even after adjusting for inflation. Discounting converts each future dollar amount associated with the project into the equivalent present dollar amount that must be invested today in the general economy in order to yield the same future amount **(cite, general literature)**.

Greenhouse gas emission control may also be viewed as an investment: money is spent today on emissions controls today so that money may be received later in the form of reduced economic costs of global warming. If the real rate of return on investment in emission reduction exceeds the rate on investment in machines and education, then future generations would be better off if less were invested today in machines and education and more in controlling greenhouse gas emissions; the converse also holds.

Discounting allows the comparison between investment returns in a particular project and investment returns in the general economy. Social scientists have debated the precise rate to use for global climate analysis (Cline 1992, Nordhaus **date**). Different conclusions have been driven in part different assumptions about expected sources of financing, and about what return the funds would have achieved in the real economy.

[expanded discussion to be inserted here]

1.4 GENERAL RESPONSES TO GLOBAL WARMING

1.4.1 *Adaptation.*

Adaptation actions enhance society's ability to withstand changes in the economic, social, and environmental system caused by climate change; where climate change has positive impacts, adaptation refers to actions that take full advantage of these effects. Adaptation will be a part of any response strategy, because proposed limitations on emissions growth will not stabilize greenhouse gas emissions. Thus the world will undergo some warming in even the most favorable case.

Adaptation will reduce damages from warming (cite). Farmers, for example, will move to different crops, and to different varieties within the same species. They can change cropping practices, such irrigating in response to hotter drier growing seasons. International trade will moderate the direct effect of climate on yields through the pricing mechanism in international commodity markets. Patterns of crop yield changes around the world along with strength of consuming sector compared to the strength of the exporting sector determines the well-being of individual countries and regions. Unlike mitigation, individual countries capture most of the benefits of adaptation; thus private market forces alone will induce nations to undertake adaptation.

1.4.2 *Mitigation.*

Mitigation may take the form of limiting emissions, or of enhancing greenhouse gas sinks. Given today's limited understanding of the climate system, mitigation provides the surest measure for avoiding the consequences of climate change. Mitigation alternatives such as non-carbon energy sources present economic environmental and health consequences of their own. Moreover, mitigation actions have a specific time path that often complicates the analysis. For example, reforesting all available land in the U.S. could significantly slow the accumulation of atmospheric carbon over the next 50 years, but not after the forests were full.

Many studies have measured the costs of mitigation actions, often using different model structures and assumptions, and yielding significantly different results. Recent model comparisons have compared economic optimization models, econometric models, and engineering optimization models, attempting to place the estimates on a common basis (EMF 1993). These comparisons find wide differences in results among different models--often greater than the differences between various atmospheric or oceanic models--but conclude that between-model differences shrink once the models are put on a common basis. They also identify key variables that drive the differences in results, in particular economic growth, substitution possibilities, the rate of energy efficiency improvement, and the future availability of carbon-rich or carbon-free energy sources.

In deciding whether to undertake costly control measures now, governments will balance the immediate costs of action (noting that technical progress will lower the cost of future reductions) against the possibility that delayed reductions must be greater and therefore more expensive.

1.4.3 *Climate Engineering.*

Climate engineering includes ocean fertilization to increase carbon uptake, and the introduction of large amounts of reflective particles into the upper atmosphere. Some studies find these options likely to be low in low cost (NAS 1991). On the other hand, they represent large-scale interventions with unknown environmental consequences and may change the nature of climate change while not avoiding all the consequences of increasing trace gases.

1.4.4 *R&D.*

Research and development can lead to greater understanding of uncertainties, reduce the cost of limiting emissions and enhancing sinks, and reduce the cost of adapting to any climate change that does occur.

1.4.5 *Timing of Mitigation.*

1.4.5.1 *Joint implementation.*

Cooperative efforts to reduce greenhouse gas emissions--either between nations or between entities in different nations--may become an important approach to climate protection. Because the warming effects of increasing greenhouse emissions anywhere are felt everywhere, and marginal costs of abatement vary across countries, joint implementation (JI) can reduce total emissions and total damages at less cost than if each nation acts separately.

At the same time, important questions have been raised about JI: what incentives would encourage JI investments; what actions would be granted JI credit against national commitments; how JI agreements would be monitored and enforced; and how JI would blend with existing development aid.

1.4.5.2 *International Trade.* (will be re-written)

Trade can significantly decrease the cost of any warming that might occur. In agriculture, for example, international trade helps determine the net economic effect of climate change on a nation, and alters comparative advantage and trade flows. Even when the net global economic impact is negligible or even beneficial, some countries will suffer significant losses and benefits. Tropical countries, for example, may be net losers even when the world as a whole benefits (Fisher, et al., Reilly and Hohmann, Reilly, et. al., and Kane et. al.) .

Trade may also increase the difficulty of reducing global emissions. Suppose the developed countries agree to reduce emissions but the LDCs do not. To meet their obligations, the developed countries would effectively raise the price of burning fossil fuels. Some production of fossil-fuel-intensive products would therefore switch to nonsignatories, where energy costs would now be relatively lower (Edmonds and Reilly

1983). Aluminum and chemical production, for example, has historically been sensitive to energy prices (Squitieri 1984). Similarly, forestation policies may be offset by forest cutting elsewhere. Moreover, non-commercial fuel (fuel not bought and sold) may present its own problems, particularly in the LDCs. For example, India and China evidently use more coal than official consumption records indicate, because small users mine coal directly or obtain it through informal unrecorded channels. Efforts to limit emissions could increase the unrecorded share of energy consumption.

Greenhouse restrictions in one region may result in carbon-intensive activities simply moving to regions without these restrictions. Calculating these carbon "leaks" depends on uncertain parameters describing international trade, and on the structure of the model used (Whalley, OECD). Only a few models represent international capital flows, meaning that most models cannot represent industry relocation (McKibben and Wilcoxen).

1.4.5.3 *International Agreements.*

The Montreal Protocol, signed in 1987, were the most far-reaching international agreement yet achieved. Many have proposed that it serve as the model for a convention on global climate change. Negotiations over a climate change convention, however, are likely to be far more difficult than negotiations over CFC limitations. Although 160 countries signed the Rio Framework Convention on Climate Change, most took many months or years to ratify. Fewer still made strong commitments to reduce emissions, and almost all of those were in the developed world. Also, the Convention commits most developed nations to provide technical and financial support to developing country parties to the Convention; most expect long and difficult negotiations over the amount and terms of this additional aid.

1.5 FRAMEWORK FOR POLICY CHOICE

1.5.1 *Introduction.*

Climate change will impose one kind of cost on societies. Preventing or adapting to climate change will impose others. Because there are competing uses for scarce resources, governments may seek policies that minimize total costs: the direct costs of climate change that cannot be avoided, the indirect costs of climate change, plus the costs of policy responses. Determining the efficient response is difficult, however, both because of the complexities and the large uncertainties involved.

The costs of climate change and costs of policy response depend on two large systems -- the climate system and the economic system -- both extraordinarily complicated in themselves, and further complicated by the linkage between economic activity and greenhouse gas emissions. Because of these interactions, some individual and teams of researchers have begun to undertake an "integrated assessment" approach, which would integrate the economic and physical systems (OECD and US citations). While conceptually appealing, the resulting complexities require the use of many simplifying assumptions.

Uncertainty also surrounds key aspects of climate modeling. For example, very little is known about regional and temporal variations in climate that might be associated with a given increase in global mean temperature; this information is key to predicting the implications of climate change both for natural ecosystems and for climate dependent human activities like agriculture. Thus it is also key to formulating national action plans.

1.5.1.1 *Goals of the Rio Convention -- Thresholds.*

The Rio Climate Convention sets as its ultimate objective "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." This objective assumes a threshold dividing dangerous concentrations from safe concentrations. Even if emissions policies must be designed to hold greenhouse gas concentrations below some specified threshold, many possible emissions paths exist to achieve this goal. The Rio Convention would not appear to proscribe considerations of warming costs and emission control costs in choosing among the possible emissions paths that achieve the overall goal of remaining below a concentration ceiling (Richels and Edmonds 1993).

1.5.2 *Paradigms of Choice.*

Several paradigms for making rational policy choices arise from economics (broadly defined) and decision theory (cite).

1.5.2.1 *Standard Cost-Benefit Analysis Paradigm.*

In a standard cost-benefit analysis, one or a few possible policy actions are specified, and the future monetary costs and benefits flowing from each policy action are estimated.

Then these future costs and benefits are converted into their present value equivalent amounts by applying appropriate discount factors to the monetary amounts that accrue in the future. Finally, the policy action with the greatest present value net benefit is identified as the best policy action to adopt (Musgrave 1959).

This approach--at least in its basic formulation--has some inherent limitations. Most important, it does not handle uncertainty well, particularly when future resolution of uncertainty may cause mid-course corrections to a earlier policy which had been based on the information available at that time (cite). This occurs because the possible policies in a cost benefit analysis are completely specified at the time of the decision, with no allowance for contingent future modification in response to new information.

Box: Cost-benefit flow diagram

Even in the absence of uncertainty, however, standard cost benefit analysis is limited as a policy analysis tool for the climate change problem, because climate change is inherently dynamic (cite). Since climate change is related to the stock of CO2 in the atmosphere, the costs and benefits of additional emissions now depend on emissions decisions made in the past, as well as on those to be made later. This interdependence between policy decisions over time requires finding a dynamically optimal path of emissions. Standard cost benefit analysis, however, would typically involve only a comparison of several emissions ceilings, none of which is likely to represent a dynamically optimal path of emissions.

1.5.1.2 *Dynamic Optimization Paradigm (Ramsey Model).*

Whereas standard cost benefit analysis assumes an arbitrary emissions trajectory and estimates the costs and benefits of choosing that trajectory, a dynamic optimization approach first defines warming costs as functions of past and current emissions levels, and costs of emission control as a function of the level of control. Then, using an optimization algorithm, it finds an emissions trajectory that is optimal in the sense that emissions in every time period reflect an optimal balance between warming cost and control costs, given the (optimal) level of emissions in the past and future time periods. Most dynamic optimization analyses of climate change have been conducted in the context of Ramsey models of optimal economic growth (Ramsey 1928, Koopmans 1967, Solow 1970).

Implicitly, an optimal emissions trajectory appropriately balances the costs and benefits of delaying emissions reductions. For example, the cost of emissions reductions might be high in the short run and relatively low in the long run, when low-carbon or no-carbon energy sources are relatively cheaper. In this case, an optimal trajectory would involve higher emissions now, and lower emissions later relative, say, to some arbitrary target emissions reduction policy (Richels and Edmonds 1993).

The chief limitation of Ramsey models (at least in their deterministic form) is that they fail to handle uncertainty. One may conduct sensitivity tests in which parameter values in a dynamic optimization are changed to see how strongly the optimal emissions trajectory is affected by such changes. Sometimes this will reveal that certain policies are relatively unaffected by parameter variations, and thus that uncertainty about these parameters does not matter for the choice of optimal policy. However, in the more general case, variation in parameter values will affect the optimal policy, and the implications of uncertainty about those parameter values cannot be determined from a (deterministic) dynamic optimization approach **(cite--R Howard?).**

Box: Dynamic optimization flow diagram

1.5.1.3 *Decision Theory Paradigm.*
Decision theory can be viewed as an extension of dynamic optimization to incorporate uncertainties. As such, it overcomes this limitation of deterministic dynamic optimization (Pratt, Raiffa, and Schlaifer 1965). It may also incorporate learning and sequential decisions. It does so, however, at the cost of considerable analytic complication, which often makes the problem intractable without simplifying assumptions to limit the range of uncertainty represented.

Decision theory methods generally require the specification and use of *subjective probabilities* of alternative *states of the world*. These probabilities are usually obtained through an interview process carried out with experts. The interview process is designed to elicit the experts' perceived odds of alternative states of the world. An expert quoting such odds for a particular state of the world should then be equally willing to take either side of a small wager that this state will prove to be true, when the payoffs to such a wager are consistent with his or her quoted odds, and assuming that the expert is risk neutral with respect to such a wager. A problem may arise if the experts' perception of risks differs from that of the general public. For example, the general public believes that risks from nuclear power accidents are much higher than experts believe, while the public perceives floods and earthquakes to be less risky than experts believe (Viscusi **date).**

1.5.1.3.1 *Learning.*
The specification of probabilities for alternative states of the world is a difficult task by itself. However, a second layer of difficulty arises because of future learning, both as a result of continued research and as a result of the accumulation of historical evidence over time. When future learning will occur, the analyst must assess the probabilities of alternative answers, and determine how such answers would then change the perceived probabilities of alternative states of the world. In general, the possibility of future learning influences the optimal emissions path today.

1.5.1.3.2 *Risk Aversion.*

Subjective probabilities may be generated by a thought experiment in which an expert contemplates a wager as if he or she were risk neutral. Society as a whole is unlikely to be risk neutral, however, with respect to actual global warming outcomes, particularly catastrophic outcomes. Thus it is necessary to incorporate risk aversion into an analysis that seeks to identify an optimal policy with respect to emissions reduction **(cite).**

Reflecting risk aversion in decision theoretic analysis is generally accomplished through the use of a risk averse ***utility function*** defined on income (or wealth) including the effects on income of emission control costs and global warming costs. Risk averse utility functions are characterized by declining marginal utility of income -- that is, at low levels of income, additional income has relatively high value, while the opposite is true at high levels of income. Consequently, an increment to income adds less to utility than an equal sized decrement subtracts from it, and a decision maker would not accept an actuarially fair wager.

Box: Simple decision tree

Many different risk-averse utility functions might be used in an analysis of emission reduction policies. Analysts have debated which is most appropriate (Pratt 1964, Arrow 1971, Wilson 1977). The connection between the degree of risk aversion reflected in the utility function and the appropriate discount rate may limit room for disagreement about these important parameters: A more risk averse utility function implies that the marginal utility of income declines faster as income rises. Since future generations are expected to have higher incomes than the present generation, using a more risk averse utility function implies a reduced willingness to sacrifice current income for future income, i.e. a higher discount rate.

1.5.1.3.3 *Weakness--Analytical and Computational Complexity.*

The chief weakness of the decision theoretic approach is the degree of analytic complexity it generates. The analyst must identify all alternative states of the world and possible new information that may be learned, and assign subjective probabilities to them. Climate change involves two large and complex systems interacting over centuries; even supercomputers will fail to solve the problem when fully specified. Thus the analyst must make simplifying assumptions, the choice of which is an important challenge in itself.

1.5.1.4 *Multi-Attribute Decision Theory Paradigm.*

One of the key difficulties in formulating a rational policy response to the climate change problem is that of expressing intangible warming damages, e.g. to ecosystems, as monetary costs. Where standard decision theory rolls this information into the utility function, multi-attribute decision theory attempts to avoid this difficulty, by employing more than just a monetary summary of warming damages, in formulating a policy response to climate change. To date, little empirical climate change analysis has followed this approach.

1.5.2 *Concepts for Policy Choice.*

A number of useful concepts arise from the social science perspective. Some are little more than common sense, others are general concepts derived from optimization or decision theory, and still others follow from early applications of rational choice paradigms to the climate change problem.

1.5.2.1 *No Regrets Policies.*

No regrets policies have positive net benefits independent of any considerations of climate change. No analysis is needed to determine that these policies make sense; they make society unarguably better off. The difficulty is in identifying them. Most analysts agree that certain proposals are truly *no regrets*, e.g. removing government subsidies to fossil fuel production in the former Soviet Union. In other cases, analysts are split. For example, consumers' choices of electric appliances or electric light bulbs are seen as clearly irrational by some, but rational by others.

1.5.2.2 Importance of Flexibility in Timing.

The timing, predictability, and flexibility of policies introduced to reduce greenhouse gas emissions will significantly affect the cost of those policies. Capital stocks in the energy using and energy producing sectors of the economy change only slowly over time, while new technologies may take decades to come into common use. Consequently, the transition to a less carbon intensive economic regime will be less costly if the transition is predictable and made gradually. In addition, the transition will be less costly if it is accomplished using flexible policy instruments. Economists note that a tax on carbon, for example, encourages emissions reductions, while allowing for inter-temporal flexibility in these reductions.

1.5.2.3 Insurance and hedging.

In the presence of uncertainty, people insure themselves against many types of losses. Insurance against greenhouse-related costs may take several forms, depending on the probability of the adverse outcome, the loss in value of the outcome, and the cost of insurance. Some urge prompt reductions in emissions as insurance against the risks of irreversible environmental damage. Others, noting that rational buyers don't buy insurance if the cost of the premium is too high in relation to the value of the possible loss, urge further scientific research before costly commitments are made for emission reductions. Still others urge development of new energy supply and conservation options, to reduce costs of mitigation and adaptation.

An optimal hedging strategy will depend on the uncertainty surrounding current knowledge, and the likelihood and timing of new supply, conservation, and adaptation strategies.

1.5.2.4 Carbon Taxes and Uncertainty.

In the presence of uncertainty about costs and benefits of controlling emissions, a tax on emissions leads to a better outcome than an emissions quota if the marginal benefit function for control is flatter than the marginal cost (Weitzman 1974). Some analysts have concluded that this condition holds for climate change policy (Peck and Teisberg 1993; Nordhaus 1993).

Suppose the function relating warming damages to greenhouse gas concentrations is smooth, i.e. with no critical thresholds. Then, because warming damages depend on the total stock of greenhouse gas emissions, damages are not much affected by any single year's emissions, and the *marginal damage* from the first ton of carbon emitted in a year is about the same as the marginal damage from the last ton emitted. By contrast, the *marginal cost* of controlling the first ton of emissions is about zero, while the marginal cost of controlling the last ton could be high.

1.5.2.5 Control Policies Under Uncertainty.

Under uncertainty, the optimal emission reduction policy may be more aggressive than it is if all uncertain variables are treated as known and equal to their mean values (Nordhaus 1993, Peck and Teisberg 1993). This is true primarily because of synergistic interactions between uncertain variables, since these interactions can produce extreme events with very high costs (Nordhaus 1993, Frankhauser 1993).

1.5.2.6 Timing of Critical Policy Decisions.

Some analysts believe that emission reductions in the next few decades will be relatively expensive, since they must be achieved primarily by reducing use of oil and gas. Oil and gas emit less carbon than coal when burned, and cost less to produce. In later decades, however, emissions reductions may be relatively less costly if they can be achieved by substituting expensive but carbon-free energy sources for moderately expensive coal-based synthetic fuels. In this case, the optimal short-run policy would not differ greatly from the "no control" policy, even though the optimal long-run policy may differ sharply from the no control policy (Peck and Teisberg 1992).

More generally, the cost to the economy will depend on the flexibility allowed in reaching an emission reduction path. For example, the goal of stabilizing emissions would cost far less if averaging is allowed among different years along the path than if emissions must not rise in any year (Richels 1993); to the atmosphere, what matters at any given time is total concentrations, not the emissions path.

1.5.2.7 Mid-Course Corrections.

In many cases, a policy choice made in the near term may prove to be a mistake in light of information discovered later, but the mistake may be corrected later by relatively modest changes in the emissions path chosen after the new information has come to light (Lemper, Schlesinger, and Hammitt 1993). Suppose that policy makers are uncertain about the extent of warming that will later turn out to be tolerable, and about the sensitivity of climate to CO_2 concentrations. Then whether they impose tight or loose controls over near-term emissions may not much affect overall costs of control. This results from the long time lag between emissions and temperature change; thus damages depend not on the flow of emissions, but on the stock of atmospheric carbon. As a result, mistakes made in one period may be fixed in the next period.

1.5.2.8 Irreversibilities.

In the presence of irreversibilities, uncertainties, and learning, an optimal policy may be cautious in the sense that irreversible commitments are postponed, pending the acquisition of better information. One study found that in the absence of threshold damage effects, the dominant irreversibility is not in the climate system, but rather in commitments to capital stocks to control emissions (Kolstad 1993). In the presence of a threshold, however, environmental irreversibilities (large irreparable changes) may dominate capital stock irreversibilities.

1.5.2.9 Value of information.

Better information leads to better decisions. Because of limits to current knowledge and the high cost of being wrong in either direction, the value of better information on climate change is likely to be great (Manne and Richels 1992, Peck and Teisberg 1993, Nordhaus 1993). Most studies of the value of information assume that in the absence of better information, an optimal policy under uncertainty will be adopted. In actual practice, however, lack of good information may lead policy makers to extreme policies (such as "do nothing" or "control everything"). If suboptimal policies would be chosen with incomplete information but better policies would be chosen with better information, the value of improved information may be many times higher than estimated using the standard assumptions of optimal decision making under uncertainty (Peck and Teisberg 1993).

1.5.2.10 Portfolio of responses.

In the presence of uncertainty, and with some statistical independence among the uncertainties, policy makers can reduce risk by adopting a portfolio of responses rather than attempting to settle on one optimal policy. A balanced portfolio of responses includes not only policies to reduce current emissions, but also funding to expand research to reduce uncertainties, and to lower the costs of future adaptation and mitigation.

Proper portfolio selection depends on interactions among the options. For example, better information on greenhouse science will influence decisions on technology development and emissions reductions. In the same way, better information on future costs of carbon-free energy sources will affect the allocation of emissions over time.

1.5.2.11 Sequential dynamic decision making.

Decisions will be made in the 1990s in the face of uncertainties about damages and long-run control costs that will not be resolved for decades. Major uncertainties will be resolved, and decisions made, during each of the next several decades. The optimal decision today depends in part on how future uncertainties will be resolved. Using a structure like that in Box 6, the techniques of probabilistic analysis may be combined with dynamic optimization to incorporate results of future research into today's decisions.

Decision tree showing learning and sequential decision making.

1.6 ECONOMICS OF POLICY ACTIONS

1.6.1 *The Ultimate Objective and Its Relationship to Intermediate Aims.*

The ultimate objective of the Framework Convention on Climate Change (Article 2) is the stabilization of atmospheric concentrations of greenhouse gases at a level that would "prevent dangerous anthropogenic interference in the climate system," within a time-frame sufficient to permit adjustment of natural ecosystems, ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner. Intermediate aims are reflected in language regarding emissions levels in the year 2000 (Article 4).

Nations are likely to reduce CO2 emissions in three ways: increasing end-use energy conversion efficiency, changing energy use patterns (e.g. land use and commuting), shifting away from energy-intensive goods and services, and shifting away from high-carbon fuels.

In production, changes in energy use will depend on investment decisions made over a long period; once an investment in productive capital is made, there is limited opportunity to reduce energy consumption per unit of output. Timing is also important on the demand side. For example, new information from climate research may abruptly shift demand for carbon-free energy sources, but producers may be unable to respond quickly.

Meeting intermediate emission reduction goals may require the early replacement of long-lived capital equipment. This may increase or decrease the cost of meeting long-term goals.

1.6.1.1 *Possible conflicts between intermediate and ultimate objectives.*

Early capital commitments to meet intermediate goals may make it more difficult to meet long-term goals. First, it may divert resources from more productive investments that would increase future income, and therefore resources for future abatement. Second, it may lock in technologies with high economic or environmental costs. Third, it may create perverse incentives to move away from long-term goals. If intermediate goals apply to only a limited group of countries and they all raise energy costs to limit CO2 emissions, production of energy-intensive manufacturing may relocate in other countries. This "carbon leakage" reduces the contribution that attainment of intermediate goals makes towards the ultimate objective.

1.6.1.2 *Possible synergies between intermediate and ultimate objectives.*

The pursuit of intermediate goals may also make it easier to achieve long-run goals. First, intermediate goals can stimulate early development of technologies that will can reduce emissions in the long-term. Second, even though intermediate goals apply directly to only a subset of countries, technologies developed to meet these goals are likely to be spread worldwide. Third, because most greenhouse gases exist in the atmosphere for a long time, intermediate-term emissions reductions may reduce the likelihood of drastic high-cost controls later. Fourth, intermediate goals may lead to accelerated replacement of existing capital stock. Some environmental regulations give a preference to existing sources. This artificially lengths the lifetime of existing facilities, and increases emission rates.

1.6.1.3 *The ultimate objective and "room" for future emissions growth.*

The safe level of future emissions will depend on 1) How much damage is done by increasing concentrations; and 2) the level of future emissions. A better understanding of economic and social processes that drive future emissions will help to illuminate this important (IPCC 1992).

1.6.2 *The Economics of Energy-Using Technology.*

Engineering cost models indicate that most nations use more energy than is cost-effective to provide lighting, heating, transport, etc. and other services. Some believe that this indicates large potential cost savings that have somehow been overlooked; if they have been, then with help from government energy planners, firms could increase profits and markedly reduce greenhouse emissions at the same time. Others believe that firms and consumers do not systematically and repeatedly overlook cost-saving opportunities; if they do not, then government planning will not improve on the market outcome, and reducing greenhouse emissions will cost real resources.

Critics of the second approach argue the obvious opportunities to profitably reduce energy use invalidates the claim that private markets lead to an efficient result, and the concept of tradeoffs along an efficiency frontier. Critics of the first approach note the lackluster performance of centrally engineered economies as evidence that the market solution defines a practical if fuzzy efficiency frontier for a dynamic economy. In their view, substituting the judgement of expert planners for verdict of the marketplace has much more downside than upside potential for the economy.

Rational analysis requires an analysis of the factors that actually influence the spread of new technology.

1.6.2.1 *Factors Influencing the Adoption of Technology.*

Social science has identified a number of factors that influence diffusion of new technology:

Information: Considered as an economic commodity, information has high fixed costs and low marginal costs of production or dissemination. Also, information producers cannot appropriate all the benefits of their efforts, as every recipient of information instantly becomes a potential competitor to its supplier. Further, information is often concentrated in the hands of those who have an incentive to misrepresent it. Thus markets for information do not reflect the usual optimality conditions that characterize well-functioning competitive markets (Stiglitz cite?).

Returns to Scale and System Effects: Some technologies might be economically attractive at a large scale of production, but not on the much smaller scale on which they might initially be adopted. Other technologies exhibit dynamic scale economies: unit cost falls over time as a function of the cumulative output of firms or industries. Technology "networks" may also affect diffusion rates. For example, cars and trucks fueled with electricity, natural gas, methanol, etc., require a refueling infrastructure, which itself competes for resources with the conventional fuel infrastructure already in place.

Risk: Because decision makers may attach a risk premium to new technologies, an unconventional technology must have a significant cost advantage before it will be adopted.

Cost and Availability of Capital: The cost-effectiveness of individual technologies is sometimes computed using a social discount rate that differs substantially from the cost of capital to decision makers. Studies of implicit discount rates consistently show that households and firms use discount rates substantially above the long-term market rate of interest (Ross, Williams and Larson 1991?; Hausman 1978).

Capital Allocation: Real-world businesses may operate by rationing a fixed amount of capital rather than accepting all projects that pass a specified hurdle rate. With rationing, the opportunity cost of investment capital may significantly exceed the social discount rate, or even the rate at which capital is available to the firm in financial markets.

Bounded Rationality: Attention is itself a scarce resource. Managers and consumers may focus product quality, labor productivity, human capital, etc., rather than energy efficiency.

Hidden Costs: Consumers value a range of attributes difficult to include in an engineering model. For example, auto buyers value not only first cost and fuel economy (which computer models can easily calculate), but also performance, safety, and durability, which they cannot.

Divergence between laboratory and in-use performance: Especially for new technologies, actual energy use often differs significantly from energy use calculated in the laboratory.

Variation across individual consumers: Engineering models generally assume an average consumer; actual consumers may display a wide range of characteristics and usage patterns.

1.6.2.2 *Impact of factors affecting adoption of technology.*

Where the factors listed above indicate market failures, policies to address these failures can advance economic efficiency while moving decisions closer to consistency with engineering evaluations. Other factors indicate unusual market conditions, but not market failures. Further, market failure in itself does not justify regulatory intervention. Regulations impose costs of their own; regulatory failures often undermine governments' attempts to correct market failures (Stigler **cite**, Buchanan **cite**).

1.6.2.3 *Opportunities for greater energy efficiency.*
The potential for greater energy efficiency may be analyzed from both technical and market perspectives. Timing is an important element of the analysis, given the long capital lifetime of energy- using capital. Also, international comparisons can provide a cross-sectional basis for the assessment of opportunities to adopt technologies and practices that would lower net anthropogenic greenhouse emissions.

1.6.2.3.1 *More efficient technology.*
Researchers believe that a reservoir of no-cost energy efficiency improvements remains to be exploited, although they disagree on the size of the reservoir. By adopting these improvements, economies would reduce CO2 emissions at zero or negative cost (U.S. OTA 1992?, Lovins **cite**, critic **cite**).

Transportation Fuel Economy: The projected rapid growth in vehicle use throughout the world, with implications for both global warming and local environmental issues, makes transportation fuel use a key leverage point in environmental policy. Fuel economy of new cars is converging across industrialized countries with widely varying fuel prices. Researchers disagree, however, on how much fuel economy will increase in the coming decades, particularly in view of the importance of performance and other non-energy attributes that buyers value (U.S. National Academy of Sciences 1992).

Use of alternative fuels is rising in some countries, driven primarily by concerns over smog and other local air pollution, problems rather than global warming. Vehicle fuels that may be attractive from a global warming perspective over the longer term include alcohol fuels from woody biomass, electricity from non-fossil sources, and fuel cells.

Industrial Energy Efficiency: A small group of industries (petroleum, primary metals, paper, chemicals, stone and glass) accounts for the majority of industrial energy use. These industries have led a steady improvement in overall industrial energy efficiency over the past two decades, especially in developed countries (**cite LBL**). Energy intensities have declined in parallel in all OECD economies over the past two decades. However, while improvement trends are broadly similar, differences in energy efficiency levels persist. These differences reflect a combination of: differences in energy pricing structures, differences in the composition of output within broad industrial classifications, and "pure" efficiency differences that reflect variation in age composition of the capital stock and production techniques across ACCEDE countries. Most developing economies and economies in transition use more energy per unit of industrial output than do the OECD economies.

Home Appliances: Appliance efficiency has increased dramatically over the past two decades, especially in developed countries. Both market forces and standards have driven this trend, especially for refrigerators and space heating and cooling equipment, the greatest energy users **(cite LBL)**.

Land Use: Because buildings have useful lifetimes of up to 50 years, the siting of buildings on land has important implications for energy use. For example, whether mass transportation and district heating can increase their market share will depend in part on population density.

1.6.2.3.2. Low-emission energy sources.
Once the reservoir of unexploited no-cost energy efficiency improvements is exhausted, low- and no-emission energy technologies will play a much more important role in reducing greenhouse gases.

Relative cost will be key. If low-carbon sources are less expensive than coal-based synthetics and other fossil-based fuels, market forces alone will lead to significant emissions reductions. Long run emissions will depend on use of the world's coal reserves, which hold much more carbon than oil and gas reserves combined. Oil and gas prices will significantly influence coal use in the short term; costs of non-fossil alternatives--or nations' willingness to pay a premium for low-carbon fuels--will determine coal use in the long term.

Several low or no-emission electricity generation technologies are already entering the market. In transportation, however, for most uses, alternative fuel vehicles still cost far more than conventional vehicles with similar performance characteristics. The ultimate market balance between these fuels and coal-derived synthetic fuels will have a significant impact on long-run emission trends.

1.6.3 ***Carbon Taxes and Related Policies.***
Three major sets of policies are available to reduce emissions: 1) command and control regulations; 2) carbon taxes; and 3) tradeable emissions permits. Economists generally believe that taxes or permits can reduce emissions at a lower cost than command and control regulations, because taxes and permits take advantage of information in the hands of producers, and of differences in control costs (Solow 1971, Baumol and Oates 1972).

The choice between taxes and tradeable permits depends on the objectives of the policy maker and nature of the uncertainty about the marginal cost and marginal benefit curves for carbon emission reductions (Weitzman 1974). Using permits, policy makers set the quantity of allowed emissions. Thus, at the start, the allowed quantity is known but the cost is not. Trading can then reveal information about control costs. Because permits are an artificially created scarce resource, however, it may be very difficult to reach consensus on the initial allocation of permits that is required to initiate a program.

Using a carbon tax, on the other hand, the marginal cost of reducing emissions is known with certainty, but the level of emissions is not. Policy makers can later revise the tax level, thereby adjusting the level of emissions.

1.6.3.1 *Carbon taxes.*
Carbon taxes reduce emissions through three types of changes: fuel switching towards low- and no-carbon fuels; reduced demand for energy-intensive products; and reduction in the amount of energy used to produce a given quantity of energy-related services, such as lighting, space conditioning, or transport.

With carbon taxes, fuels with a high carbon content per unit of energy become relatively more expensive than low- or no-carbon fuels. The relative price of coal with a carbon tax increases more than that of other fuels because it has a high carbon content per BTU and a relatively low economic value per BTU. Renewable and nuclear fuels, which have no carbon, will become relatively less expensive than fossil fuels. Because of the long lifetime of capital goods, the full effect of fuel switching may not be felt for decades.

Whether conservation of fuel switching is more important depends on many factors including the size of the tax, how long it is in effect, the price of alternative fuels, and technological progress in developing low- and no- carbon supply sources. Model results differ widely. In a recent study that examined the costs of holding carbon emissions flat at 1990 levels, conservation ranged from 30 to 90 percent of total reductions, depending on the model used (Energy Modeling Forum, 1993).

Carbon taxes may also dampen economic growth, although researchers differ on the size of the loss. Depending on which model is used, using carbon taxes to hold U.S. carbon emissions at 1990 levels could result in GDP losses in 2010 ranging from 0.1 to 0.7 **(check)** percent of GDP in 2010, and 0.2 to 1.7 percent of GDP by 2030 (Energy Modeling Forum 1993, **check percentages**). Carbon taxes reduce GDP because they displace otherwise productive capital into investments aimed at decreasing carbon emissions.

The adverse impacts of a carbon tax on GDP can be partially or wholly offset by simultaneously reducing other taxes. If tax reduction matches carbon tax receipts, then the package of tax changes is revenue neutral. Recent studies indicate significant potential for mitigating GDP losses by reducing taxes on labor and investment (Goulder, DRI). To date, researchers have focused on GDP rather than consumption, although carbon taxes may affect consumption and GDP in very different ways.

1.6.4 ***Market Structure Reform.***

1.6.4.1 *Market reforms that also reduce greenhouse gas emissions.*
Unregulated competitive markets will not produce efficient allocations if the private and social costs of either production or consumption of a good diverge. Reforms that

remove market distortions will increase market efficiency even without consideration of the benefits of reduced emissions of greenhouse gases.

Removing Energy Subsidies: Subsidies to energy production and consumption are widespread throughout the world. Coal production in particular is heavily subsidized in both developed and developing countries. Many developing countries also subsidize energy consumption to end users (World Bank 1992). Equity considerations may motivate subsidies to production and consumption; alternatives to energy subsidies, however, can achieve the same equity goals while lowering emissions.

Property Rights Reform: Ill-defined property rights encourage overconsumption of resources. A clearer definition of property rights could be particularly important in helping to decrease deforestation, for example, while improving economic efficiency. Regulating non-greenhouse externalities: Many activities that produce greenhouse emissions may also generate other kinds of pollution. For example, fossil fuel combustion releases conventional air pollutants; rush-hour auto use contributes to road congestion. Taxes, externality adders, congestion pricing, or tradable permits can correct these problems, resulting in lower emissions of both greenhouse gases and other pollutants.

Unit Pricing of Waste Disposal to Encourage Recycling. The "life-cycle" social cost of consuming a good includes its production plus its disposal cost. Most consumers, and many businesses, pay a flat fee for trash disposal; with a flat fee, the marginal cost of throwing away an extra pound of trash is zero. By moving from flat fees to unit pricing, the actual price consumers pay to buy and dispose of a good will more closely match its full life-cycle social cost.

Pay-at-the-Pump Automobile Insurance: In most countries, drivers pay their automobile insurance yearly or monthly. Once the premium is paid, the marginal insurance cost of driving an extra mile is zero, even though driving more does increase the chance of being in an accident. Alternatively, drivers could be required to pay a portion of their insurance bill at refueling. With pay-at-the-pump insurance, a tax would be levied on gasoline and earmarked to pay for insurance premiums. This would raise the cost of gasoline at the pump, but lower auto insurance premiums.

1.6.4.2 *Policies to Induce Innovation.*

Future emissions and the long-run cost of emissions reduction depend on the rate of technology advancement as well as the diffusion of currently available technologies. Private markets alone may invest too little in research and development, for the same reason that they may invest too little in other forms of information: the producers or discoverer of the information does not get all the benefits of the discovery.

Governments may increase resources devoted to technology development and the effectiveness of these investments by:

a. Tax incentives to lower the cost of R&D while leaving project selection in the hands of the private sector. Maximum impact per dollar of tax expenditure is achieved by linking incentives to increased R&D expenditures on the margin, rather than to total R&D expenditure.

b. Technology forcing regulations. For example, vehicle emissions standards in many countries have spurred development of low-emissions engines. On the other hand, poorly conceived regulations can retard innovation. For example, requiring "best available" emission control technology may discourage innovation if firms expect that any new approach developed result in tighter standards.

c. Government-sponsored basic research. Private-sector firms may then apply this basic research to commercial products.

1.7 NATIONAL ACTION PLANS

Countries are assembling action plans in anticipation of the first meeting of the Conference of the Parties. The plans are being assembled from the actions described above: market efficiency improvements, government efficiency improvements, new technology development and cooperation internationally, sink enhancement, and research.

[comparison of the U.S. with at least one other plan will be made]

The United States mitigation program of October 1993 (The Climate Change Action Plan, October 1993) can be used as one example of a plan that uses several different types of actions to meet its stabilization goal. The 50 actions included in the plan can be grouped into 5 major categories.

The main components of the U.S. plan are as follows:
- enhancement of greenhouse gas sinks
- facilitation of technology development and cooperation
- improvement of market efficiency
- improvement of government efficiency
- research

[more detailed discussion will follow: the share of the program that each component represents and the goals of the overall program]

1.8 SUSTAINABLE DEVELOPMENT

1.8.1 *What is sustainable development?*

Different observers have defined sustainable development in different ways. The Brundtland Commission (**date**) offered this interpretation:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs ... Living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability.

The Interamerican Development Bank (**date**) suggested this definition:

> Development that distributes the benefits of economic progress more equitably, protects both local and global environments for future generations, and truly improves the quality of life.

Among economists, Robert Solow makes the case that sustainable development is

> an injunction to preserve productive capacity for the indefinite future. That is compatible with use of nonrenewable resources only if society as a whole replaces used-up resources with something else (Solow, 1992)

From the point of view of the social sciences, sustainable development requires that future generations be able to achieve a standard of living at least equal to that of the current generation. Thus sustainable development refers more to intergenerational equity than to economic efficiency.

Several rules may define a sustainable development path. One rule would ensure constant levels of capital stocks over time, where capital stock is defined broadly to include man-made capital (such as roads and factories), human capital (an educated population), and natural capital (such as forests). The capital stock in turn depends on the rate of saving, broadly defined, and the rate of technical change.

The global challenge of sustainable development is to meet this criterion in a world where population will increase by 50% or more by the middle of the next century. Thus the correct measure of success is per capita welfare, not aggregate welfare, implying a resource base that meets the needs of far more people than are alive today.

1.8.2 *The Need for a Broader Definition of GDP.*

In setting targets for sustainable development, the current system of national accounts has been considered too narrow on several grounds (Daly and Cobb 1989, Sterrer 1993):

1) Defects in reflecting current welfare. GDP and similar measures indicate changes

only in traded goods and services, omitting many activities important in the measurement of human welfare.

2) Inadequacy of measuring environment and natural resources. National income accounts do not reflect possible deterioration of a nation's resource base. Economic activity measured by GDP may not represent a sustainable path over the long run.

3) Incomplete measure of output. Standard national income accounts overlook the production of some undesirable outputs, such as pollution; for example, increased expenditures on medical services resulting from increased pollution levels are now counted as a gain in GDP. Further, while conventional the standard accounts properly include depreciation of certain forms of capital (plant and equipment, buildings), they neglect depreciation of natural resources and environmental capital.

1.8.3 *Modifying National Accounts.*

Four approaches are commonly used to calculate changes in the natural environment (Peskin and Lutz 1990):

a) The environmental expenditure approach, used recently in the United States, identifies pollution abatement and other expenditures but leave conventional GDP unchanged;
b) The physical accounting approach, used in Norway and France, uses physical units of measurement to account for flows and stocks of resources;
c) The depreciation approach adjusts gross and net product by subtracting out the value of natural resource depletion (Repetto 1989); and
d) The comprehensive approach uses both physical measures and value (Statistical Office of the United Nations 1992).

Some nations are already modifying their national income accounts using these approaches. The United States, for example, has been redesigning its economic accounts to include natural resource accounting, following the guidelines of the International System of National Accounts, including an integrated set of current and capital accounts, sector by sector. This work will result in a fully developed capital account, allowing decision makers to make trade offs with a view of both natural and man-made capital, consistently covered and appropriately valued.

As an alternative index intended to be more closely related to human welfare, the UN Development Program has proposed the human development index or HDI (UNDP 1990). The HDI gives a composite measure of human development by combining three key indicators: longevity (measured by life expectancy at birth), education (measured by adult literacy and mean years of schooling), and income (real GDP per capita adjusted for purchasing power). Although the HDI is not directly related to global environmental issues, both global warming and abatement policies may affect it.

1.8.4 *Implications of sustainable development for developing countries.*

The poorer nations will experience the largest increase in population, and the greatest pressure to consume their resource base. At the same time, they often cannot command the investment to replace depleted resources, nor do they have the technological resources to offset the loss of their capital stock. These obstacles will make it difficult for many developing countries to achieve a sustainable development path.

1.8.5 *Sustainable development and the risks of climate change.*

Climate change imposes special demands on the ability to achieve sustainable development. A rapidly or unpredictably changing climate can disturb orderly economic development plans. Shifting agricultural production regions, for example, can result in the diversion of capital resources that would have been available for other more productive uses. The costs of mitigation and adaptation may take resources from necessary consumption, and may crowd out investment that would make sustainable development possible. Responding to climate change increases the uncertainty and the cost of achieving sustainable development. At the same time, sustainable development does not mean that all resource stocks remain unchanged; an increase in capital stock can substitute for a decrease in other resources.

Developing countries face particular burdens; their development is likely to be the most affected by the risks of climate change. Many potential environmental consequences--such as rising sea levels--will particularly affect developing countries simply because of their location. At the same time, they often lack the financial and technical resources to respond. Further, many developing countries rely heavily on fossil fuels either for export earnings or for energy consumption, and thus would feel the impact of fossil fuel restrictions. Developing countries can move closer to a sustainable development path by rationalizing resource pricing and otherwise removing barriers to markets. At the same time, these improvements are not likely to offset the increased costs of slower development.

1.8.5.1 *Population change.*

Increasing population increases the demand on resources, including energy. The world's population is growing at the rate of 1.7% p.a. (World Bank, 1992). Under the World Bank's base case projection, world population would stabilize at 12.5 billion sometime after 2050, more than double the current total, with 95% of the increase in developing countries. Population growth is expected to contribute to pollution of water, air, soils, in addition to problems of deforestation, and loss of biodiversity.

1.8.5.2 *Energy use.*

Population pressures and economic development will result in greater energy use, which in turn will increase CO_2 emissions. The consumption of commercial energy in developing countries is rising rapidly and will soon dominate growth in energy consumption--and thus CO_2 emissions--worldwide. In 1985, LDCs including China contributed 19% of worldwide carbon emissions. By 2020, LDCs are expected to contribute ---% of a larger total (World Bank, 1992).

Some researchers have proposed that LDCs address economic growth and environmental concerns simultaneously by "leapfrogging" earlier development paths (Goldemberg, 1987). By adopting modern energy sources (electricity, renewable liquid and gaseous fuels, etc.), and new energy-efficient technologies, LDCs would decouple energy use from economic growth, just as the industrialized countries are doing by the shift to services, and to less energy-intensive materials. Whether this is a practical development path remains to be seen.

1.8.5.3 *Deforestation.*

Developing countries also contribute to net increases of greenhouse gas emissions by deforestation. In recent years, deforestation, nearly all from developing countries, contributed about 24% of net greenhouse gas emissions (Goldemberg, 1992).

1.8.5.4 *Poverty.*

Although substantial progress has been made in the last 25 years, more than one-fifth of humanity still live in acute poverty. In the late 1980s, many regions saw earlier gains slowed or even, as in Africa, reversed. World Bank analysts expect a decline in the incidence of poverty over the next decade in Latin America, Asia, and Eastern Europe, but an increase in poverty in Africa (World Bank, 1992). The recently demonstrated link between poverty and pollution (Grossman and ----, 1992) has led some to call for measures to increase the pace of development as an approach to the issue of environmental quality in the LDCs (reference).

1.9 WHAT IS KNOWN ABOUT CLIMATE CHANGE?

Social scientists are in general agreement on some points of climate change analysis. This section lists those points on which there is general consensus.

- *Value of information.*
  Better information leads to better decisions. Because of limits to current knowledge and the high cost of being wrong in either direction, the value of better information on climate change is likely to be great.

- *Importance of insurance and hedging*
  Insurance against greenhouse-related costs may take several forms, depending on the probability of the adverse outcome, the loss in value of the outcome, and the cost of insurance. An optimal hedging strategy will depend on the uncertainty surrounding current knowledge, and the likelihood and timing of new supply, conservation, and adaptation strategies.

- *Importance of flexibility in timing*
  The timing, predictability, and flexibility of policies introduced to reduce greenhouse gas emissions will significantly affect the cost of those policies. Capital stocks in the energy using and energy producing sectors of the economy change only slowly over time, while new technologies may take decades to come into common use. Consequently, the transition to a less carbon intensive economic regime can be less costly if the transition is predictable and made gradually. In addition, the transition will be less costly if it is accomplished using flexible policy instruments, including carbon taxes and tradable permits.

- *Carbon taxes, tradable emission permits*
  Carbon taxes or tradable permits can reduce greenhouse emissions at a lower cost than command-and-control regulations, because taxes and permits take advantage of information in the hands of producers, and of differences in control costs.

- *Market structure reform*
  Many reforms that remove market distortions, including removing subsidies to coal producers and to energy consumers, will reduce greenhouse emissions.

- *Irreversibilities.*
  In the presence of irreversibilities, uncertainties, and learning, an optimal policy is likely to be cautious in the sense that irreversible commitments are postponed, pending the acquisition of better information.

- *Portfolio of responses.*
  In the presence of uncertainty, and with some statistical independence among the uncertainties, policy makers can reduce risk by adopting a portfolio of responses rather than attempting to settle on one optimal policy. A balanced portfolio of

responses includes not only policies to reduce current emissions, but also funding to expand research to reduce uncertainties, and to lower the costs of future adaptation and mitigation.

- *Sequential dynamic decision making.*
  Decisions will be made in the 1990s in the face of uncertainties about damages and long-run control costs that will not be resolved for decades. Major uncertainties will be resolved, and decisions made, during each of the next several decades. The optimal decision today depends in part on how future uncertainties will be resolved. The techniques of probabilistic analysis may be combined with dynamic optimization to incorporate results of future research into today's decisions.

- *Importance of extreme events*
  Many of the costs of climate change are likely to stem from extreme climatic events: days of extreme heat or drought, increased severity of storms, etc. Conversely, some of the benefits will result from a reduction in extreme events, for example, fewer days of killer frosts in some cold regions.

- *Low-cost energy efficiency improvements*
  A reservoir of low-cost energy efficiency improvements remains to be exploited, although the size of the reservoir is disputed.

- *Joint implementation*
  Cooperative efforts between nations to reduce greenhouse gas emissions can reduce total emissions and total costs at less cost than if each nation acts separately.

- *Large uncertainties in computed results*
  Economic models of greenhouse emission mitigation show wide variation among models, although the differences narrow when the models are run on a comparable basis. In the long run, their results will depend critically on GDP growth, etc., which cannot be predicted with any accuracy. As a result, economic models are likely to vary at least as much as physical science models, on which they often depend.

- *Importance of flexibility, time path*
  The cost to the economy of reducing greenhouse emissions will depend on the flexibility allowed in reaching an emission reduction path.

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(as of December 24, 1993)

Program

IPCC Working Group III
Tsukuba Workshop on Policy Instruments and Their Implications
: 17-20 January 1994, Tsukuba, Japan

Background : You may recall that the IPCC (Intergovernmental Panel on Climate Change) has been jointly established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to make technical-scientific assessments of various issues related to climate change and to provide scientific and technical advice to the Intergovernmental Negotiating Committee on a Framework Convention on Climate Change (INC). Working Group III of the IPCC is charged with assessing the socio-economics of the impacts and of response options to climate change. The Working Group is also examining and assessing available greenhouse gas emission scenarios. A broad subject area within the preview of the Working Group is that of policy instruments including economic, regulatory and other instruments.

Purposes : The workshop will focus on :

(i) developing inputs to the Second Assessment Report of the IPCC expected to be completed in late 1995 ;

(ii) informing experts on the status of the current understanding of available policy instruments and their applicability in different national contexts ;

(iii) providing experts with an opportunity to exchange information on regional problems as well as providing a briefing to policy advisors the latter mainly for the Asian-Pacific region on the nature and scope of the Working Group's activities.

Venue & Timing : Tsukuba workshop will be held at Tsukuba Center for Institutes (KENKYU KORYU CENTER), 2-20-3 Takezono, Tsukuba, Ibaraki 305, Japan, Tel. +81-298-51-1331. The opening session will be from 9:00 am on Monday 17 January 1994. Registration desk will be set up in the venue in the morning 8:00 to 9:00 am. Welcome party will be from 17:00 on Monday.

Session Schedule (tentative) :

Monday January 17 Policy Instruments 1

Session 1 9:00-10:30 **Opening**
(1) Opening Address
Dr.James Bruce, Co-Chair, WG III, IPCC
Dr.Hoesung Lee, Co-Chair, WG III, IPCC
Dr.N.Sundararaman, Secretariat, IPCC
Dr.Atsunobu Ichikawa, Director General, NIES, JAPAN
(2) Scope of the Work of Policy Instruments
Dr.Brian Fisher, Australian Bureau of Agricultural and Resource Economics, AUSTRALIA

Session 2 10:45-12:15 **Taxes (Review)**
(1) Climatic Change Policy and International Trade (i)
Prof. Scott Barret, London Business School, U.K.
(2) Carbon/Energy Taxes & Developing Countries
Mr.Anwar Shah, The World Bank, U.S.A.

Session 3 13:45-15:15 **Taxes (Consequence)**
(1) International Effectiveness of Carbon/Energy Taxes
Mr. Andrew Dean, OECD

(2) Domestic Effectiveness of Carbon/Energy Taxes
Prof.Dale Jorgenson, Harvard Univ.,U.S.A.
(3) Taxes & the Economics of Stabilizing Atmospheric CO_2 Concentrations
Dr. James Edmonds, Battelle Pacific Northwest Lab., U.S.A.

Session 4 15:30-17:00 **Forestry,Public Awareness & Environmental Auditing**
(1) Land Use Programs for Conservation of Forest
Dr.Steve Rayner, Battelle Pacific Northwest Lab.,U.S.A.
(2) The Role of Public Policy in Communicating the Effectiveness of Energy Efficiency Information Program
Ms.Juddy Gregory, Applied Energy Research Group, U.S.A.
(3) Environmental Auditing
Mr. Yoshiyuki Ishii, Environment Policy Office, Hitachi Ltd., JAPAN

17:00-19:00 **Welcome Party**

Tuesday January 18 Policy Instruments 2

Session 5 9:00-10:30 **Regulatory Instruments & Administrative Guidance**
(1) Direct regulations in Environmental Policies, a review
Mr. Jip Lenstra, Ministry of Housing, Physical Planning & Environment, The Netherlands
(2) Standards and Administrative Guidance
Prof.Hidefumi Imura, Kyushu Univ., Japan

Session 6 10:45-12:15 **Subsidies & Financial Incentives**
(1) Incentives to Environmental Innovations
Prof. Stefan Schleicher, Univ. of Graz, AUSTRIA
(2) Energy Conservation Measures and their Applicability in Developing Countries
Dr.Amulya Reddy, International Energy Initiative, INDIA

Session 7 13:45-15:15 **Tradable Permits (1)**
(1) A Dynamic Game Approach to Greenhouse Policy
Dr.Brian Fisher, Australian Bureau, AUSTRALIA
(2) Lessons from U.S. Experience
Mr. Stephen Harper, EPA, U.S.A.

Session 8 15:30-17:00 **Tradable Permits (2)**
(1) Forests to Capture Carbon : Tradable Permits Scheme
Dr.Roger Sedjo, Resources for the Future, U.S.A.
(2) Enforcement of International Tradable permission
Prof.Tom Tietenberg, Colby College, U.S.A.

Wednesday January 19 Policy Instruments 3

Session 9 9:00-11:00 **Other Economic Instruments**
(1) The feasibility of Joint Implementation of Carbon Emissions Reductions
Prof.Peter Bohm, Stockholm Univ., SWEDEN
(2) Joint Implementation
Mr.Tom Jones, OECD
(3) Tradable Absorption Obligations
Prof.Peter Read, Massey Univ.,NEW ZEALAND
(4) Deposit Refund Schemes
Prof.Kazuhiro Ueta, Kyoto Univ.,JAPAN

Session 10 11:15-12:15 **Policy Mix & Portfolio of Instruments**
(1) Climatic Change Policy and International Trade (ii)
Prof. Scott Barret, London Business School, U.K.

(2) Policy Mix in Developing Countries
Dr.Rajendra Pachauri, TATA, Energy Institute, INDIA

Session **11** 13:45-15:15 **Implementation in Developing Countries**
(1) Issues of Implementation in Developing Countries
Dr. Ali Azimi, ADB, PHILIPPINES
(2) Energy Policies for Sustainable Development in Developing Countries
Prof.Zhou Dadi, Energy Research Institute, CHINA

Session **12** 15:30-17:00 **Concluding**
Dr.Brian Fisher, Australian Bureau, AUSTRALIA
Prof. Masahiro Kuroda, Keio Univ.,JAPAN

Thursday January 20 Regional Session
-Economic Measures & Their Implications for Asia-Pacific Region-

Session **13** 9:00-10:30 **Opening & Discussion 1**
(1) The Overview of the Scope of WG III & Views from Asia-Pacific
Dr.Hoesung Lee, Co-Chair, WG III, IPCC
(2) Introduction to Discussion 1
-Asian-Pacific Characteristics & Socio-Economic Assessments in the region-
Dr.Rajendra Pachauri, TATA, Energy Institute, INDIA

Session **14** 10:45-12:15 **Discussion 2**
(1) Introduction to Discussion 2
-The Joint Implementation & Co-Operated Research in Asia-Pacific region
Mr. Ir. Aca Sugandhy, Ministry of Environment, INDONESIA
(2) Closing Address from the Local Organizing Committee
Prof. Akihiro Amano, Kobe University, JAPAN

(Discussion between Speakers and Discussants follows after presentations in each session on policy instruments. WG III: Working Group III)

Sponsors : The Governments of Japan and Australia, Keio University and IPCC.

Organizing Committee :
Dr. James Bruce, Co-Chair , IPCC/WG III (Chair, Canadian Climate Center)
Dr. Hoesung Lee, Co-Chair, IPCC/WG III (President, Korea Energy Economics Institute)
Dr. Richard Odingo, Co-Vice-Chair, IPCC/WG III (Kenya)
Dr. Ted Hanish, Co-Vice-Chair, IPCC/WG III (Director of Labor, Norway)
Dr. Eric Haites, Technical Support Unit, IPCC/WG III (Canada)
Dr. Brian Fisher, IPCC/WG III(Australian Bureau of Agricultural and Resource Economics)
Prof. Scott Barrett, IPCC/WG III (London Business School, U.K.)
Prof. Peter Bohm, IPCC/WG III (Stockholm University, Sweden)
Mr. Anwar Shah, IPCC/WG III (The World Bank, U.S.A.)
Prof. John Mubazi, IPCC/WG III (Makerere University, Uganda)
Prof. Robert Stavins, IPCC/WG III (Harvard University, U.S.A.)
Prof. Akihiro Amano, IPCC/WG III (Kobe University, Japan)*
Prof. Masahiro Kuroda, IPCC/WG III (Keio University, Japan)*
Dr. Tsuneyuki Morita, IPCC/WG III (National Institute for Environmental Studies, Japan)*
Prof. Hidefumi Imura, (Kyushu University, Japan)*
Dr. Kenji Yamaji, (Central Research Institute of Electric Power Industry, Japan)*
Prof. Kanji Yoshioka, (Keio University, Japan)*
Dr. Shuzo Nishioka, (Center for Global Environmental Research, NIES, Japan)*
*: Local Organizing Committee

Official Language : English (no interpretation)

Registration : Your registration prior to the workshop is requested. Please inform your attendance by returning the attached registration form via fax or mail. Registration fee is free.

Accommodation : Participants to the WS can stay at Tsukuba Dai-ichi Hotel near the venue at the WS special rate (about ¥10,000 for a single). Reservation is available through the WS Official Travel Agency, NEW ORIENT EXPRESS Ltd. (Contact Person : Tsukasa Simoda / Hiroshi Koshikawa, Tel. +81-298-55-7111, Fax. +81-298-55-7115)

Transportation :

- From Narita New Tokyo International Airport to Tokyo Station (by Limousine Bus,90 min.,¥2800 or by JR Line/Narita Express, 60 min. ¥2890), Tokyo Station to Tsukuba Center Bus Terminal (by JR Bus or Kanto Bus from Yaesu South Exit of Tokyo Station, 65 min.,¥1230). Tsukuba Center Bus Terminal to Tsukuba Dai-ichi Hotel (3 min. on foot), Tsukuba Center Bus Terminal to Tsukuba Center for Institutes (KENKYU KORYU CENTER)/the venue (13 min on foot).
- From Narita New Tokyo International Airport to Tsukuba Center for Institutes (KENKYU KORYU CENTER)/the venue or Tsukuba Dai-ichi Hotel (by taxi, 80 min. about ¥14000).
- Note : The Secretariat will not assume to responsibility for any taxi or travel fare.

Climate : January in Tsukuba can be cold. (The average temperature in January is 2 to 3 °C/ 36 to 37 °F.)

Secretariat : Executive Secretary : Shuzo Nishioka Program Coordinator : Ichiro Higashi
Center for Global Environmental Research (CGER)
National Institute of Environmental Studies (NIES)
16-2 Onogawa, Tsukuba, Ibaraki 305, JAPAN
Fax : +81-298-58-2645 Tel : +81-298-51-6111 X 375/485

CGER

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IPCC WG III Tsukuba Workshop

Registration Form

Fax to : **The Secretariat of Tsukuba Workshop** at CGER, NIES, JAPAN
Fax: +81-298-58-2645

From : Title: ( )Prof. ( )Dr. ( )Mr. ( )Ms. : Check off with V

Name (print):____

Position/Division:____________________________________

Affiliation:____

Address:____

____

Country:____

Fax: ____________________ Tel:____________________

E-mail: ____________________

I will participate in Tsukuba Workshop.

Signature:____

Note: Rapporteurs are recruited ! Please register yourself for the WS rapporeteur list by checking off ( ) with V. Thank you very much.

( ) I will be able to play the role of a rapporteur.

Dec.1 , 1993

Routes to the Venue

Routes to the Center

TSUKUBA CENTER FOR INSTITUTES
Science and Technology Agency
2-20-3, Takezono, Tsukuba, Ibaraki, 305, JAPAN
TEL: 0298-51-1331

Narita New Tokyo International Airport

- Limousine Bus. ¥ 2,800 by about 90 min.-ride → **Tokyo Station**
- JR Line (Narita Express) ¥ 2,890 by about 60 min.-ride → **Tokyo Station**
- Keisei Line (Sky Liner) ¥ 1,740 by about 60 min.-ride → **Ueno Station**
- about ¥14000 80 min. -taxi ride → **Tsukuba Center for Institutes**

Tokyo Station

Direct Bus (JR Bus, Kanto Bus:Yaesu South Exit) ¥ 1,230 by about 65 min.-ride → **Tsukuba Center Bus Terminal**

- Tsukuba Dai-ichi Hotel: 3 min. on foot
- Hotel Suwa: 30 min. on foot; About ¥ 1,000 by 10 min.-taxi ride

→ **Tsukuba Center for Institutes**

Tokyo Station / Ueno Station

JR Line(Joban Line) → **Arakawaoki Station***

- Hotel Suwa: About ¥ 2,500 by taxi ride

* Only local train is available.

¥ 2,520 by 50 min.-express ride → **Tsuchiura Station**

- Tsukuba Dai-ichi Hotel: About ¥ 2,000 ~ 3,000 by 20 min.-taxi ride

→ **Tsukuba Center for Institutes**

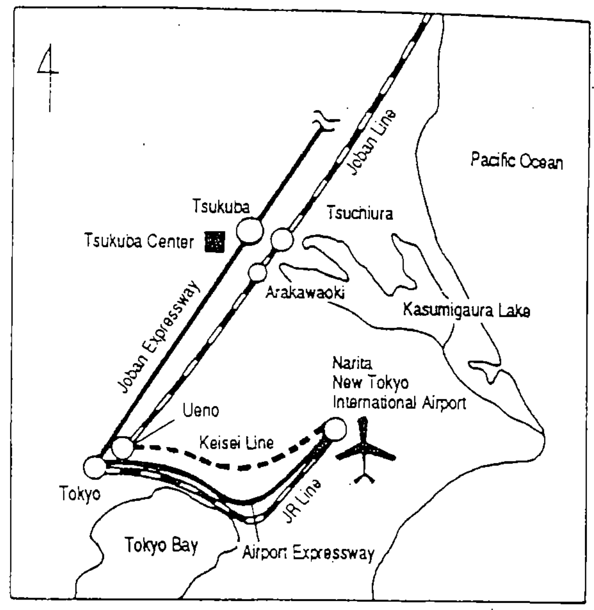
From Tokyo Station
Take the Tsukuba Express Bus bound for Tsukuba Center at the Yaesu South Exit of Tokyo Station, and get off at Tsukuba Center (Bus Terminal). Tsukuba Center for Institutes is a 13 minute walk from Bus Terminal.

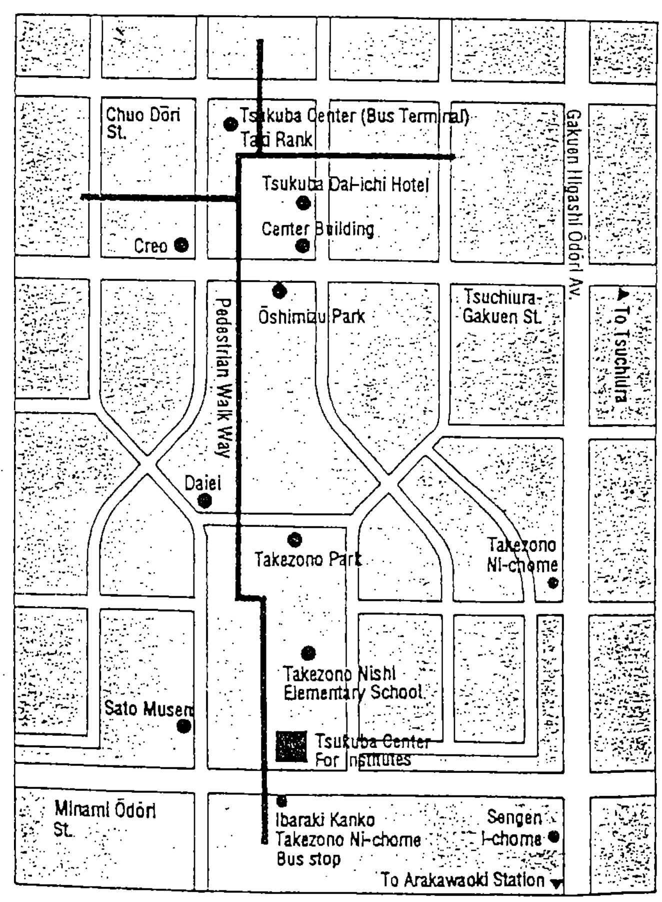
From JR Arakawa-oki-Station
Take the bus bound for either Tsukuba-daigaku-chuo, Kenchiku-kenkyusho or Kokudo-chiri-in at the east exit of the station, and get off at Sengen-i-chome. Tsukuba Center for Institutes is a 7 minute walk from the bus stop.

From JR Tsuchiura-Station
Take Ibaraki-kanto-bus bound for either Ishige, Shimana, Higashi-arai or Kamigo at the gate #2 near the west exit of the Station, and get off at Takezono-ni-chome. Tsukuba Center for Institutes is in front of the bus stop.

From Joban Expressway
Use the Sakura-Tsuchiura interchange.

TSUKUBA





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(as of December 16, 1993)

IPCC Working Group III
Tsukuba Workshop on Policy Instruments and Their Implications
: 17-20 January 1994, Tsukuba, Japan

ー政策手段とその影響についてのIPCC第3部会ワークショップー

背景：IPCC(気候変動に関する政府間パネル)は国連環境計画(UNEP)と世界気象機関(WMO)により設立された。その目的は気候変動に関する諸課題について技術的、科学的な評価を行うとともに気候変動枠組み条約会議(INC)に対し、科学技術面で支援を行うことである。IPCC第3作業部会では気候変動の影響および対策についての社会経済学的評価、ならびに温室効果ガス排出シナリオについての評価検討を行っている。経済的施策、規制等の政策手段の検討は第3作業部会の諸活動の中でも最も幅広い分野の一つである。

ワークショップの目的:

(i) 1995年に予定されているIPCC第2次評価報告書への寄与

(ii) 政策手段ならびにその異なる諸国における適用可能性についての現在までに得られた知見のレヴュー

(iii) 地域特性についての専門家による情報交換ならびにアジアー太平洋圏の政策関係者への第3作業部会諸活動の紹介

会場：科学技術庁　研究交流センター
〒305つくば市竹園2－20－3　TEL0298－51－1331
（つくばセンターバスターミナルより徒歩13分、JR荒川沖駅よりTaxi15分）

会期：
1月17日（月）～19日（水）　政策手段とその影響
1月20日（木）　アジア太平洋圏セッション
1月17日（月）8：00より受付
1月17日（月）17：00より懇親会

言語：英語（通訳はございません。）

参加登録：会場の都合上、人数に限りがありますので早めにお申込み下さい。
氏名、称号、所属、住所、郵便番号、国、電話番号、FAX番号を下記宛に郵便またはFAXでお知らせ下さい。登録料は無料です。

宿泊：筑波第一ホテル（ﾜｰｸｼｮｯﾌﾟ割引有）／ホテルスワ
（宿泊申込先：ﾆｭｰｵﾘｴﾝﾄｴｷｽﾌﾟﾚｽ（株）担当：下田TEL0298－55－7111）

参加申込および問い合わせ先：
〒305つくば市小野川16－2国立環境研究所地球環境研究センター内
つくばワークショップ事務局
事務局長　西岡　秀三、　担当　東　一郎
TEL0289－51－6111　FAX0298－58－2645

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NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDIES

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Dr. Joseph Stiglitz
Council of Economic Advisors
White House
Washington, D.C.
U.S.A.

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WASHINGTON DC 20500-0005

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United States Department of State

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Bureau of Oceans and International Environmental and Scientific Affairs

Washington, D.C. 20520

July 16, 1993

TO : IWG/GEA Subgroup on Global Climate

FROM: Daniel Reifsnyder, Director
Office of Global Change JRL for DAR

SUBJECT: IPCC Working Group III Authors

For your information, following is the final list of nominees and suggestions for Working Group III authors which was sent today to the Working Group III secretariat and co-chair.

Also attached, please find suggestions we received from Mary Gant for possible contributing authors on health effects. At today's meeting, Debra Davis of HHS, was also put forward as a possible contributing author for the health effects section. Please contact Lysbeth Rickerman if you would like to lend your support to, or have any reservations concerning, these nominations.

*IWG/GEA SUBGROUP ON GLOBAL CLIMATE

Agency	Contact	Phone	Fax
Army/CW	Eugene Stakhiv	**355-2072	**355-3171
AID	Martin Hanratty	647-7071	647-8595
CEA	Jonathan Wiener	395-5012	395-6947
DOD	John Thomas	**614-6550	**693-5305
DOE	Dirk Forrister	586-6210	586-7644
DOI	Steve Ragone	**648-4450	**648-5470
DOJ	Chuck Sheean	514-4361	514-4231
DOL	Ron Dobson	219-6203	219-5071
DOT	Robert Thurber	366-4813	366-7618
EPA	Dennis Tirpak	260-8825	260-6405
INR	Jack Schick	**482-9682	**790-5736
ITA	Bill Sugg	482-1466	482-0170
JCS	LT CDR Jane Dalton	**614-6632	**693-9379
NASA	Nancy Maynard	358-2559	358-2770
Navy	Scott Sandgathe	**696-4102	**696-3945
NEC	Heather Ross	456-7090	456-2223
NIH	Mary Gant	***496-2919	***496-0563
NOAA	Carmen Blondin	482-5647	482-4307
NSC	Eileen Claussen	395-4985	395-1590
NSF	Robert Corell	357-9715	357-9629
ODP	Brian Burke	456-7777	456-7739
OEP	Marc Chupka	395-6551	456-2710
OMB	Chantale Wong	395-6840	395-1067
OMB	Janet Pillar	395-4605	395-5651
OSTP	Bob Watson	456-6202	395-3719
OVP	Dana Marshall	395-6013	395-6042
Treasury	Michael Kaplan	622-1242	622-1228
USDA	Gary Evans	**235-9018	**235-9046
USTR	Sandy Gaines	395-7320	395-3911

*Where agencies have provided a specfic point of contact for the Subgroup on Global Climate, they are listed; where a specific point of contact for this Subgroup has not yet been provided, points of contact for the NSC/IWG are listed; to provide a specific point of contact for the Subgroup on Global Climate please call Granville Sewell (State/OES/EGC) at (202) 647-4069; fax: (202) 647-0191.

**Area code 703
***Area code 301

SEEGC Doc 4543:revised:7/12/93

U.S. NOMINATIONS FOR WG III AUTHORS

*Scope (lead)

-- Joseph E. Stiglitz, Professor of Economics, Stanford, and Council of Economic Advisors

Ch 1: Framework (lead)

-- Kenneth Arrow, Professor of Economics and Operations Research, Stanford

Socioeconomics of climate change in relation to the need for sustainable development (contributing)

-- Harold Jacobsen, Professor of Political Science, University of Michigan
-- Thomas Schelling, Professor of Economics, University of Maryland
-- Geoff Heal, Professor of Economics, Columbia University

Decision making under uncertainty, Risk assessment (contributing)

-- Kip Viscusi, Professor of Economics, Duke University
-- Hadi Dowlatabadi, Associate Professor of Economics, Carnegie Mellon University
-- Anthony Fisher, University of California, Berkeley

Methods and applications of cost/benefit analysis (contributing)

-- Paul Portney, Economist, Resources for the Future
-- Robert Pindyck, Professor of Economics, MIT

Equity considerations (contributing)

-- Amarta K. Sen, Professor of Economics, Harvard University
-- Dale Jamieson, Professor of Philosophy, University of Colorado

Value of Information (contributing)

-- Jim Hammitt, Economics Department, RAND corporation; soon to be at Harvard Center for Risk Analysis
-- Howard Kunreuther, Professor of Management, Wharton School, University of Pennsylvania

*Ch 2: Benefits (lead)

** V. Kerry Smith, Professor of Economics, North Carolina State University
-- William Nordhaus, Professor of Economics, Yale University
-- William Cline, Senior Fellow, Institute for International Economics

Agriculture (contributing)

-- Tim Mount, Professor of Economics, Cornell University
-- John Reilly, Economist, U.S. Department of Agriculture
-- Cynthia Rosenzweig, Goddard Institute
-- Diane Liverman, Pennsylvania State University
-- Sally Kane, U.S. National Oceanic and Atmospheric Administration

Water (contributing)

-- Kathleen Miller, National Center for Atmospheric Research
-- Catherine Seegerson, University of Connecticut

Biodiversity Valuation (contributing)

-- Robert Repetto, World Resources Institute
-- Gardner Brown, University of Washington
-- Andrew Solow, Woods Hole Oceanographic Institute

Health Effects (contributing)

-- (nominations to follow)

Forestry (contributing)

-- Clark Binkley, University of British Columbia
-- Roger Sedjo, Resources for the Future

Greenhouse Gas Indexes (contributing)

-- Henry Jacoby, Professor of Management, Sloan School, MIT

Integration (contributing)

-- Gary Yohe, Professor of Economics, Wesleyan
-- Joel Scheraga, U.S. Environmental Protection Agency

Ch 3: Costs (lead)

-- John Weyant, Director, Energy Modeling Forum, Stanford University

Modeling: Top Down Approach (contributing)

- -- Alan Manne, Professor of Operations Research Emeritus, Stanford University
- -- Dale Jorgenson, Professor of Economics, Harvard University
- -- Richard Morgenstern, U.S. Environmental Protection Agency
- -- Abe Haspel, U.S. Department of Energy

Modeling: Bottom Up Approach (contributing)

- -- Jayant Sathaye, Lawrence Berkeley Laboratory; developing country issues
- -- Robert Williams, Energy Laboratory, Princeton; energy efficiency, renewables
- -- Virginia McConnell, Resources for the Future

*Ch 4: Response strategies (lead)

-- Robert Stavins, Associate Professor, Kennedy School of Government, Harvard University

Contributing Authors

- -- Wallace Oates, Professor of Economics, University of Maryland
- -- Scott Barrett, London Business School
- -- Dan Dudek, Professor of Economics, MIT
- -- Thomas Tietenberg, Professor of Economics, Colby College
- -- James Poterba, Professor of Economics, MIT
- -- Richard Schmalensee, Professor of Economics, Joint Program on Climate Change, MIT
- -- Emilio Moran, Professor of Anthropology, Indiana University; deforestation, remote sensing
- -- Donald Rosenthal, U.S. Department of Energy
- -- Jessica Matthews, U.S. Department of State

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FACSIMILE TRANSMISSION COVER SHEET

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TOTAL PAGES Cover + 0	DATE 16 July 1993

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I still don't have any info on Leticia Menchaca.

Table Contents 12/24 (page off (IPCC)

1.1 OVERVIEW. . . . 3

1.2 HUMAN ACTIVITY AND GLOBAL WARMING. . . . 4
1.2.0 *Alternative Expressions of Goals.* 4
1.2.1 *Effects of Economic Activity on Climate.* 5
1.2.1.1 *Effects of Climate on Economic Activity.* 7
1.2.1.2 *Mitigation Actions.* 7
1.2.1.3 *Adaptation Actions.* 7
1.2.2 *Sources of Uncertainty in the Links Between Human Activities and Global Warming.* 7
1.2.2.1 *Uncertainties in atmospheric chemistry.* 8
1.2.2.2 *Uncertainties in general circulation models* 9
1.2.2.3 *Regional and temporal uncertainties* 9
1) What determines the affect of climate on actual economic activity? 10
1.2.2.5 *Changes in variability.* 12

1.3 THE COSTS OF GLOBAL WARMING 12
1.3.1 *Tangible Costs of Warming* 12
1.3.1.1 *Sea level rise.* 12
1.3.1.2 *Agricultural production.* 12
1.3.1.4 *Water Resources.* 13
1.3.1.5 *Heating and cooling costs.* 13
1.3.2 *Intangible Costs of Warming.* 14
1.3.2.1 *Ecosystem damages.* 14
1.3.2.2 *Species loss.* 14
1.3.2.3 *Amenity values* 14
1.3.2.4 *Human Health.* 15
1.3.4 *Nonlinearities and irreversibilities.* 15
1.3.5 *Intergenerational Equity.* 15
1.3.5.1 *Discount rate.* 16

1.4 GENERAL RESPONSES TO GLOBAL WARMING 17
1.4.1 *Adaptation.* 17
1.4.2 *Mitigation.* 17
1.4.3 *Climate Engineering.* 17
1.4.4 *R&D.* 18
1.4.5 *Timing of Mitigation.* 18
1.4.5.1 *Joint implementation.* 18
1.4.5.2 *International Trade.* 18
1.4.5.3 *International Agreements.* 19

1.5 FRAMEWORK FOR POLICY CHOICE 20
1.5.1 *Introduction.* 20

1.5.1.1 *Goals of the Rio Convention -- Thresholds.* 20
1.5.2 ***Paradigms of Choice.*** 20
1.5.2.1 *Standard Cost-Benefit Analysis Paradigm.* 21
1.5.1.2 *Dynamic Optimization Paradigm (Ramsey Model)* 21
1.5.1.3 *Decision Theory Paradigm.* 22
1.5.1.3.1 *Learning.* 22
1.5.1.3.2 *Risk Aversion.* 22
1.5.1.3.3 *Weakness--Analytical and Computational Complexity.* 23
1.5.2 ***Concepts for Policy Choice.*** 23
1.5.2.1 *No Regrets Policies.* 24
1.5.2.2 *Importance of Flexibility in Timing.* 24
1.5.2.3 *Insurance and hedging.* 24
1.5.2.4 *Carbon Taxes and Uncertainty.* 24
1.5.2.5 *Control Policies Under Uncertainty.* 25
1.5.2.6 *Timing of Critical Policy Decisions.* 25
1.5.2.7 *Mid-Course Corrections.* 25
1.5.2.8 *Irreversibilities.* 25
1.5.2.9 *Value of information.* 25
1.5.2.10 *Portfolio of responses.* 26
1.5.2.11 *Sequential dynamic decision making.* 26

1.6 ECONOMICS OF POLICY ACTIONS 26
1.6.1 ***The Ultimate Objective and Its Relationship to Intermediate Aims.*** 26
1.6.1.1 *Possible conflicts between intermediate and ultimate objectives.* 27
1.6.1.2 *Possible synergies between intermediate and ultimate objectives.* 27
1.6.1.3 *The ultimate objective and "room" for future emissions growth.* 27
1.6.2 ***The Economics of Energy-Using Technology.*** 27
1.6.2.1 *Factors Influencing the Adoption of Technology* 28
1.6.2.2 *Impact of factors affecting adoption of technology.* 29
1.6.2.3 *Opportunities for greater energy efficiency* 29
1.6.2.3.1 *More efficient technology* 29
1.6.2.3.2. Low-emission energy sources. 30
1.6.3 ***Carbon Taxes and Related Policies.*** 30
1.6.3.1 *Carbon taxes* 31
1.6.4 ***Market Structure Reform.*** 32
1.6.4.1 *Market reforms that also reduce greenhouse gas emissions.* 32
1.6.4.2 *Policies to Induce Innovation* 32

1.7 NATIONAL ACTION PLANS 33

1.8 **SUSTAINABLE DEVELOPMENT** 33

1.8.1 ***What is sustainable development?*** 33

1.8.2 ***The Need for a Broader Definition of GDP*** 34

1.8.3 ***Modifying National Accounts*** 35

1.8.4 ***Implications of sustainable development for developing countries*** 35

1.8.5 ***Sustainable development and the risks of climate change*** 35

1.8.5.1 *Population change* 36

1.8.5.2 *Energy use* 36

1.8.5.3 *Deforestation.* 36

1.8.5.4 *Poverty* 37