

**International Society for Ecological Economics
Internet Encyclopaedia of Ecological Economics**

Climate Change

Richard B. Howarth

Environmental Studies Program, Dartmouth College, Hanover, New
Hampshire 03755, USA

+1-603-646-2752 (voice), +1-603-646-1682 (fax),

RBHowarth@Dartmouth.edu

February 2003

1. Introduction

The scientific basis of climate change has been well recognized since the seminal contribution of Svante Arrhenius in the 1890s [1]. As Arrhenius noted, greenhouse gases – which include carbon dioxide, nitrous oxide, methane, water vapor, and certain industrial chemicals such as chlorofluorocarbons – are transparent to sunlight but selectively absorb the infrared radiation through which the Earth returns energy to space. In effect, greenhouse gases trap heat in the atmosphere, so increases in their concentrations should give rise to accompanying increases in mean global temperature. Although greenhouse gas concentrations were stable in the period preceding the industrial revolution, activities such as fossil fuel combustion, deforestation, and land-use change have since caused carbon dioxide concentrations to increase from 280 to 370 parts per million by volume [8]. In close parallel, industrial processes and agricultural activities have led to increases in the concentrations of nitrous oxide, methane, and other greenhouse gases. These changes are associated with the 0.6°C increase in mean global temperature that was observed between 1900 and 2000 [8].

According to current estimates, greenhouse gas emissions would lead to an additional temperature rise of 1.4 to 5.8°C over the course of the next century in the absence of corrective policies [8]. The degree of climate change that will occur is linked to uncertainties about two general sets of factors, future emissions trends and the sensitivity of climate to greenhouse gas concentrations. While it is generally agreed that carbon dioxide emissions from fossil fuel combustion will be the principal cause of future climate change, there are large uncertainties concerning the economic and technological factors that will determine future emissions – the rate of economic growth, the energy intensity of production and consumption, and the mix of high- and low-carbon fuels in meeting energy needs. In addition, climatologists are uncertain about the extent to which cloud formation might amplify or dampen the direct effects of rising greenhouse gas concentrations. The impacts of clouds on climate are not well understood and depend on the relative importance of two offsetting effects: the role of clouds in (a) reflecting sunlight as it enters the atmosphere and (b) trapping infrared radiation emitted by the Earth.

2. Climate Change Impacts and Response Options

The potential impacts of climate change have received extensive attention in the scientific literature [6]. The warming observed during the late 20th century, for example, was correlated with the melting of glaciers in alpine and polar systems and a small rise in sea level due to an influx of fresh water and the thermal expansion of the oceans. Over the next one hundred years, additional melting and a further sea level rise of 0.1 to 0.9 meters are anticipated. Climate change would alter the level and distribution of rainfall in ways that would put pressure on water supply systems while exacerbating the frequency and severity of both floods and droughts in certain world regions. While climate change would extend growing seasons in temperate regions, increased maximum temperatures would reduce agricultural productivity in tropical environments. In addition, climate change would: expand the ranges of tropical diseases such as cholera and malaria; contribute to an increase in the frequency and severity of tropical storms; and lead to pervasive changes in the structure and functioning of natural ecosystems. On this last point, some scientists believe that climate change might lead to the substantial loss of coral reef ecosystems over the course of the coming decades. In addition, climate change would most likely lead to substantial reductions in the species richness of forest ecosystems, as complex communities that are well adapted to their environments are replaced by simpler communities consisting mainly of generalist species that can cope with rapidly changing conditions.

The policy response to global warming is governed by the United Nations Framework Convention on Climate Change, which calls for the “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” (Article 2). This international treaty, which was negotiated at the Rio Earth Summit in 1992, has since been ratified by 188 nations. As a first step towards the achievement of this objective, the signatories agreed to the terms of the Kyoto Protocol in 1997. The Kyoto agreement requires industrialized nations to reduce greenhouse gas emissions by an average of 5% relative to 1990 levels by the year 2012 while deferring commitments on the part of developing countries until an unspecified future date. Although the United States withdrew from the Kyoto Protocol in 2001, the agreement is now being implemented by the majority of its signatories. The scientific community, however, agrees that stabilizing climatic conditions would require much greater reductions in greenhouse gas emissions than those required the under protocol. Greenhouse gases – in particular carbon dioxide – have atmospheric residence times on the order of a century or more. Hence major changes in climate would continue to occur even if emissions were frozen at current levels.

3. Costs and Benefits

The costs of climate change response strategies have been closely studied by economists using a variety of models and analytical frameworks [7]. The costs of complying with the Kyoto Protocol, for example, have been analyzed using so-called “top-down” models that simulate the supply and demand for energy resources and the feedbacks between emissions abatement and economic growth. Top-down models suggest that achieving the Kyoto targets using a tax on carbon dioxide emissions would impose direct costs in industrialized

nations equivalent to 0.2 to 2.0% of economic output in the year 2010. These costs, however, could be significantly reduced if emissions tax revenues were used to lower pre-existing taxes on labor and capital that impose a deadweight loss on the macroeconomy. In addition, abatement costs could be held down using the so-called “flexibility mechanisms” of the Kyoto Protocol, which involve: (a) international emissions trading; and (b) the Clean Development Mechanism, through which industrialized nations may partially satisfy their Kyoto targets by financing emissions abatement projects in developing countries.

A second approach to analyzing the costs of greenhouse gas emissions abatement is provided by so-called “bottom-up” models, which are based on the analysis of particular technologies using the methods of engineering economics [7]. In general, bottom-up studies find that baseline estimates of future greenhouse gas emissions could be reduced by as much as 20% through the full adoption of cost-effective technologies in buildings, transportation, industry, and agriculture. Much of this potential is related to opportunities to enhance the efficiency of energy use, though bottom-up studies have also examined the potential to sequester carbon dioxide through afforestation and reforestation projects, especially in developing countries. Since anticipated trends in technology and economic activity imply that baseline emissions will rise substantially over time, this emissions reduction potential will not be sufficient to achieve the targets established under the Kyoto Protocol. Bottom-up studies, however, suggest that targeted policy interventions – such as energy efficiency standards for buildings, vehicles, lighting systems, and equipment – could play an important role in minimizing the cost of greenhouse gas emissions abatement. This potential is typically overlooked by top-down models, which limit their focus to policies such as emissions taxes or tradable permits.

Economists have also intensively studied the costs of climate change and hence the benefits of greenhouse gas emissions abatement [6]. With some exceptions, this line of literature has focused on the impacts that climate change might impose on market goods and services in high-income nations given a doubling of greenhouse gas concentrations relative to the preindustrial norm, which would induce a long-term temperature increase of roughly 2.5°C. Given a temperature increase of this magnitude, impacts such as sea-level rise, changes in water resource availability, altered crop yields, and changes in energy use due to altered heating and cooling requirements might impose net economic costs equivalent to 1.5 to 2.0% of world economic output [5]. It is important to note, however, that much larger costs might fall on developing countries, which are disproportionately dependent on peasant agriculture and which lack the resources and infrastructure required to adapt to extreme weather events. In addition, there is disagreement in this literature concerning the valuation of biodiversity loss and the impacts of climate change on natural ecosystems. While some analysts believe that these impacts might be of little economic significance, others note that climate change would have pervasive ecological consequences and that today’s societies devote considerable resources to ecological conservation. With this in mind, impact cost studies should be viewed as incomplete and subject to wide margins of error.

4. Criteria for Policy Evaluation

How should the costs and benefits of greenhouse gas emissions abatement be balanced in formulating optimal climate change policies? At least two major approaches to answering this question have been advanced in the literature. Advocates of the “precautionary principle” argue that, although modest degrees of climate change might lead to moderate impacts to which future society could successfully adapt, high levels of climate change would impose an unacceptable risk of catastrophic outcomes on future generations [4]. As noted above, most impact assessment studies have limited their scope to a projected temperature increase on the order of 2.5°C. This level of warming, however, is likely to occur during the course of the current century, with much larger temperature increases arising in the more distant future. There are several pathways through which a long-term temperature increase in excess of 2.5°C might impose costs far in excess of those described in the preceding paragraph [6, 8]:

1. A disruption or shutdown of the thermohaline circulation in the North Atlantic Ocean, which is essential to maintaining Europe’s now moderate climate and the long-term removal of greenhouse gases through transfer to the deep ocean.
2. The collapse of the Greenland and/or West Antarctic Ice Sheets, which could lead to a long-term sea level rise of several meters with the inundation of coastal ecosystems and human settlements.
3. Positive feedbacks between climate change and its impacts on ecological systems, including the possible release of large stocks of greenhouse gases that are currently stored in soils and biomass.

While none of these impacts is considered to be likely, risk averse decision makers might rationally choose to limit the accumulation of greenhouse gas concentrations to “safe” (or non-dangerous) levels as required by the Framework Convention on Climate Change. The level of climate change that would forestall “danger” is a matter of some controversy. Emphasis has been placed, however, on stabilizing carbon dioxide concentrations at a level as low as 450 parts per million, which would constitute an increase of some 60% relative to the pre-industrial norm. Achieving this target would require the reduction of carbon dioxide emissions by more than 50% relative to current levels over the course of the next century, and would contribute to stabilizing mean global temperature at a level 1.5 to 3.9°C above current conditions [8].

Cost-benefit analysis provides an alternative approach to identifying optimal climate change response strategies [5]. In cost-benefit analysis, the choice of the discount rate used to balance the short-term costs and long-term benefits of greenhouse gas emissions abatement plays a crucial role in the determination of optimal policies. In the opinion of some analysts, future net benefits should be discounted at a rate equal to the long-run return available on investments in corporate stocks, which averaged 6% per year over the course of the 20th century [9]. When this assumption is coupled with “best guess” estimates of emissions abatement costs and the quantifiable damages imposed by future climate change, the cost-benefit approach suggests that only modest steps towards climate stabilization are economically justified. This result is unsurprising since a 6% discount rate implies that one dollar of benefits that accrue one hundred years from the present is worth less than 0.3

cents today. Although some models assume that the discount rate falls over time as the capital stock deepens and the return on investment goes down, this effect is generally too small to alter the qualitative conclusions described in this paragraph.

The use of high discount rates has been challenged by authors who believe that cost-benefit analysts should attach equal weight to the utility or welfare of present and future generations [2, 3]. In a world of rising incomes, this assumption might be consistent with the use of a low (1% per year) monetary discount rate since the marginal utility of consumption would fall over time. In addition, the use of low discount rates might be justified based on considerations of risk. As is well known, the 6% rate of return that investors demand on stocks is dominated by a risk premium that compensates them for the volatility of financial markets. Greenhouse gas emissions abatement, in contrast, is best viewed as a risk management strategy that would reduce a potential (but uncertain) threat to future welfare. Since investors accept returns of roughly 1% per year on safe investments such as short-term government bonds, there are good reasons to reject the use of high discount rates in the economics of climate change. When low discount rates are employed in cost-benefit analysis, aggressive steps towards climate stabilization emerge as socially optimal. In this case, cost-benefit analysis and the precautionary principle yield closely similar policy recommendations.

5. Common but Differentiated Responsibilities

To conclude this discussion, it is important to note that the Framework Convention on Climate Change defines a set of “common but differentiated responsibilities” in which concrete steps are taken to ensure that greenhouse gas emissions abatement does not compromise the pursuit of improved living standards in low-income developing nations. In historical terms, greenhouse gas emissions have been strongly dominated by today’s industrial societies. The Framework Convention is based on the moral premise that – at least in the short run – affluent nations should take the lead in shouldering the costs of climate stabilization.

It remains to be seen whether emissions can be first stabilized and then permanently reduced as people in developing countries adopt the lifestyles and technologies associated with prosperity. The answer to this question will depend on the development and commercialization of technologies that are currently constrained by issues of technical feasibility and/or economic cost – advanced energy efficiency measures, non-carbon energy supply options, and/or the removal and disposal of the carbon dioxide that is generated by fossil fuel combustion. Thus far, concerns about economic costs and burden sharing have hindered progress towards climate stabilization, especially since emissions abatement costs will fall most heavily on the politically influential energy and automobile industries and their respective labor unions. The Kyoto Protocol, however, offers a significant first step. International negotiations on this matter will no doubt continue in the coming years and decades.

Bibliography

- [1] Arrhenius, S. 1896. "On the Influence of Carbonic Acid in the Air upon the Temperature on the Ground." *Philosophical Magazine* 41: 237-276.
- [2] Broome, J. 1992. *Counting the Cost of Global Warming*. Cambridge, United Kingdom: White Horse Press.
- [3] Cline, W.R. 1992. *The Economics of Global Warming*. Washington: Institute for International Economics.
- [4] Howarth, R.B. 2001. "Intertemporal Social Choice and Climate Stabilization." *International Journal of Environment and Pollution* 15: 386-405.
- [5] Intergovernmental Panel on Climate Change. 1996. *Climate Change 1996: Economic and Social Dimensions of Climate Change*. New York: Cambridge University Press.
- [6] Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability*. New York: Cambridge University Press.
- [7] Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: Mitigation*. New York: Cambridge University Press.
- [8] Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: The Scientific Basis*. New York: Cambridge University Press.
- [9] Nordhaus, W.D. 1994. *Managing the Global Commons*. Cambridge, Massachusetts: MIT Press.