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# Are the economic costs of stabilising the atmosphere prohibitive?

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**Abstract**

Macro economic studies of the costs of reducing $CO_2$ emissions generally estimate the global cost of stabilising the atmospheric concentrations of $CO_2$ in the range 350–550 ppm in trillions of USD. This creates the impression that the cost of $CO_2$ reductions is so large that it threatens economic development. But, presented in another way, a completely different picture emerges. There is widespread agreement amongst the more pessimistic macro economic studies that stringent carbon controls are compatible with a significant increase in global and regional economic welfare. Even if the cost of $CO_2$ abatement rises to 5% of global income per year by the end of this century, this reduction is minor compared with the tenfold increase in global income that is expected. Since income is assumed to grow by a couple of percent per year, the trillion USD cost could also be expressed as a few years delay in achieving an order of magnitude higher income levels. Similar observations can also be made as regards near term abatement targets such as the Kyoto protocol. A more widespread recognition of the fact that carbon abatement policies will only marginally affect economic growth, is likely to increase the willingness to introduce carbon abatement policies.


*Keywords:* Atmospheric stabilization; $CO_2$; Economic top–down models

## 1. Very large climate changes are projected

Fossil fuels are cheap, abundant and relatively easy to handle. They powered the industrial revolution that created the material wealth of the now developed countries. Many developing countries intend to repeat that pattern of Victorian industrial development powered by fossil fuels. At present, they provide 80% of the global energy requirements and given that the human population will likely approach 9–10 billion people by the end of this century and that there is a wide spread demand to increase the material standard of living to the level that prevails in the North, one can expect increasing use of fossil fuels, in particular coal, over this century. This also means increasing carbon dioxide emissions. Business as usual scenarios for the global energy system typically suggest that global emissions will reach 15 ± 10 Gton C/year by the end of the 21st century

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(IPCC, 1995, 1999). This has the potential to triple by 2100 AD and more than quadruple $CO_2$ concentrations after 2100 AD compared with pre-industrial levels, and thus to severely alter global climate. According to the latest assessment by the Intergovernmental Panel on Climate Change, the global average surface temperature is projected to increase by 1.4–5.8 °C over the next 100 years (IPCC, 2001a).

The United Nations Framework Convention on Climate Change (UNFCCC) ratified by 181 parties, calls for nations to constrain climatic changes so as 'to prevent dangerous anthropogenic interference with the climate system'. Precise calculations of what is 'dangerous' is not possible, since (a) the degree of harm any level of climate change would bring is itself subject to a variety of uncertainties; and (b) because, whether any level of risk is 'acceptable' or 'dangerous' is a value judgement about costs and benefits weighed over a variety of 'numeraires' i.e. measures of impact such as monetary loss, loss of life, loss of biodiversity, loss of cultural heritage sites or changes in the distribution of welfare across time, income groups or peoples (Azar and Rodhe, 1997; Schneider et al., 1999).

In order to stabilise global climate at a safer level, atmospheric concentrations of $CO_2$ may have to be stabilised at 500 ppm or below (see Azar and Rodhe, 1997, for a discussion on atmospheric stabilisation targets). This would allow some near term increases in global carbon emissions, but they would eventually have to drop to well below current emissions, let alone most scenarios of future emissions. It has been asserted that this would be 'extremely costly' (Nordhaus, 1990). But is that necessarily the case?

Closing the gap between where we are heading and what we may have to do is a major challenge for citizens, business, and politicians as well as national and global institutions. Nevertheless, after having reviewed the global energy economy literature, we conclude that such stabilisation targets can be met. We find, perhaps somewhat surprisingly, that there is widespread, if not unanimous agreement, amongst energy economy analysts (as expressed through their analytic works), that substantially reducing the risks of global climate change and significantly improving the economic well being of the citizens of the world are consistent goals.

## 2. Substantial reduction in emissions is technically feasible, but at what cost?

The technical feasibility of stabilising $CO_2$ concentrations well below a doubling has been demonstrated in several global energy scenarios, for instance the LESS scenarios of IPCC (Ishitani et al., 1996), the ecologically driven scenarios in the joint study by the International Institute for Applied Systems analysis and World Energy Council (Nakicenovic and et al., 1995), the Fossil Free Energy Scenario by Stockholm Environment Institute (Lazarus, 1993) and the global energy and transportation scenarios developed by Azar et al. (2000). These scenarios allow a substantial increase in the use of energy services in developing countries, further increases in the material well being throughout the world, but still manage to stabilise atmospheric $CO_2$ concentrations at 415 ppm or below. In the near term, this is mainly done by increasing end-use energy efficiency and substituting natural gas for coal, but also by a rapid expansion of the use of renewables (see Johansson et al., 1993; Azar et al., 2000; WEA, 2000).

In the longer run, renewables become even more important since the adoption of carbon free energy technologies is necessary in order to meet the low carbon emission targets, e.g. biomass, wind and solar, which has an enormous physical potential. The solar influx to Earth is roughly 10 000 times larger than the global anthropogenic energy use. Decarbonisation of fossil fuels, i.e. the use of fossil fuels with little or no $CO_2$-emissions (for instance via electricity and hydrogen production), only plays a minor role in just one of these scenarios, but rapid progress in this field would further increase the possibility to meet the objectives in the climate convention (Parson and Keith, 1998; Schneider, 2001). Obersteiner et al. (2002) point out the possibility to use biomass energy with carbon sequestration. This would offer society energy carriers without carbon (electricity and hydrogen) and, at the same time, remove $CO_2$ from the atmosphere as long as there is storage capacity for the sequestered $CO_2$.

The optimism expressed in the technical feasibility of such renewables-rich scenarios or a hydrogen economy should not lead us to underestimate how different such development scenarios are from most conventional projections of our long-term energy future (Hoffert et al., 1998; Bolin and Kheshgi, 2001). Although it is widely debated whether obstacles to the penetration of such technologies arise from their higher costs, the neglect of externalities from conventional energy systems or perverse subsidies to the status quo systems, the one point that emerges clearly is that business as usual will lead to multiples of current $CO_2$ concentrations in the long term and that the transition to a low greenhouse gas emissions pathway needs to begin as soon as possible if very large increases in $CO_2$ concentrations are to be avoided.

Although the technical feasibility of meeting low atmospheric $CO_2$-stabilisation targets has been demonstrated, there is still concern about the economic costs of realising such or similar targets. Here, a longstanding debate between bottom–up and top–down modellers has taken place. The former perspective, mainly advocated by physicists and engineers, has focused on energy use per se and the potential to improve energy efficiency. Several studies have concluded that the potential for such reductions is large (see e.g. Goldemberg et al., 1987; Lovins and Lovins, 1991; Department of Energy, 1997; National Academy of Sciences, 1991; Ayres, 1994; WEA, 2000).

These and other studies support the view expressed by the US former President Clinton (1998) in a speech to the US congress: "Every time we have acted to heal our environment, pessimists have told us it would hurt the economy. Well, today our economy is the strongest in a generation and our environment is the cleanest in a generation. We have always found a way to clean the environment and grow the economy at the same time. And when it comes to global warming, we'll do it again."

The top–down perspective is dominated by economists, many of whom believe that correcting energy system technical inefficiencies will have transaction costs as large or larger than the costs of the energy inefficiencies and thus they do not believe that such 'no regrets' failures in energy system markets exist. The debate sometimes takes on a religious character, with assertions and counter assertions about (largely undemonstrated) costs or benefits flung about by both sides.

The more pessimistic models used by some economists generally find deep reductions in carbon emissions to be seemingly prohibitively costly—and count in trillions of dollars. In the latest IPCC assessment, the cost of stabilising the atmospheric concentration of $CO_2$ at 450, 550 and 650 ppm is estimated to lie in the range 2.5–18 trillion USD, 1–8 trillion USD and roughly 0.5–2 trillion USD, respectively, (see chapter 8 of Working Group III of the latest IPCC assessment, IPCC, 2001c). The cost does not only depend on various technology and economy assumptions but also the emissions trajectory towards the target (see Wigley et al., 1996). For instance, reaching 450 ppm would according to Manne and Richels (1997) cost the world between 4 and 14 trillion USD, with the lower cost reflecting a (more) cost-effective emission trajectory towards the stabilisation target.

Yale economist William Nordhaus argued a decade ago that 'a vague premonition of some potential disaster is insufficient grounds to plunge the world into depression' (Nordhaus 1990). More recently, Linden claims that stabilisation of the atmospheric concentrations of greenhouse gases 'would essentially destroy the entire global economy' (Linden 1996). Or similarly, Hannesson in his textbook on petroleum economics argues that 'if the emissions of $CO_2$ are to be stabilised or cut back at least one of two things must happen. Either the poor masses of the world will continue their toil in poverty or the inhabitants of the rich countries will have to cut back their standards of living to levels few would be willing to contemplate' Hannesson (1998). Greenhouse sceptics Michaels and Balling (2000) are concerned that the science of global warming could be used as a 'basis for sweeping policy recommendations that could gravely harm US prosperity'.

## 3. Are the costs of stabilising $CO_2$ concentrations prohibitive?

The purpose of this paper is not to reassess the relative merits of top–down and bottom–up models. Rather, we make the perhaps somewhat paradoxical observation that resolution of this still implacable debate may have surprisingly little significance for the larger policy debate over how much 'climate insurance' to buy. Simply put, both types of models, even the more pessimistic top–down models, support the conclusion that substantial reductions of carbon emissions and several fold increases in economic welfare are compatible targets.

In this connection, Schneider (1993) in a comment on the Nordhaus (1992) DICE model, pointed out that DICE calculated that the draconian 20% emissions cut (that had been advocated at the time by a number of environmental groups and some governments) that DICE found costly and economically inefficient only delayed a century-long 450% per capita income growth from simulated year 2090 to about 2100 in the model. Schneider argued that a decade delay in achieving a phenomenal income growth was surely a politically palatable planetary insurance policy to abate half of global warming.

In order to illustrate this, we make conservative (i.e. at the larger end of the range) cost assumptions (that the top–down modelling perspective is essentially correct): assume that for every ton of carbon emission avoided, it costs the global economy 200, 300 and 400 USD, on average for the 550, 450 and 350 ppm cases, respectively. (A 100 USD per ton C tax would raise the cost of electricity from natural gas and coal by roughly 0.01 and 0.02 USD per kWh, respectively, and the cost of gasoline by roughly 0.07 USD per l).

The higher costs associated with the lower concentration targets are introduced in order to reflect the deeper and more immediate emission reductions and the associated higher transition costs. Further, we assume that global income and carbon emissions develop close to the IPCC IS 92a scenario: income grows by a factor of ten (2.1% per year) over the period 1990–2100 and global carbon emissions reach 19 Gton C/year by 2100. Further, we assumed carbon reduction rates that grow logistically over time and set the discount rate of 5% per year (another typical, but highly debatable, assumption).

Under these assumptions, we estimate the present value of the future abatement costs at 18 000, 5200 and 1900 billion USD for reaching 350, 450 and 550 ppm, respectively. (The numbers are discounted to 1990 and given in 1990 USD. We chose 1990 in order to facilitate comparison with the IPCC estimates mentioned earlier which are expressed in 1990 USD).

Some may claim that even these conservative cost assumptions are too optimistic, whereas others will argue that they are too pessimistic. However, our purpose is not to attempt to calculate the (very uncertain) exact costs of these reductions, rather they are chosen to reflect typical cost-estimates obtained by most top–down modellers. Our real intention is to show how such costs compare with the projected economies of the future as given in the same top down models.

Obviously, 18 trillion USD is a huge cost—as top–down modellers repeatedly assert. The annual output of the global economy in 1990 amounts to some 20 trillion (1990) USD. Seen from this perspective (18 vs. 20 trillion USD), these estimates create the impression that we have to make prohibitive cuts in our material standard of living in order to reduce the emissions so as to stabilise concentrations below a doubling of $CO_2$. To some, the cost-estimates are perceived as an unaffordable insurance premium (unless it were believed that unabated climate damages would amount to the lion's share of the GDP, see Roughgarden and Schneider, 1999).

However, viewed from another perspective, a different picture emerges. This is clearly illustrated in Fig. 1 where the expected global income pathway without any carbon abatement is compared with the global income pathway in the case with carbon emission reductions leading to stabilisation of the atmospheric concentration of $CO_2$ in the range 350–550 ppm. The current concentration is around 370 ppm. The global income in the 350, 450 and 550 ppm scenarios is generated using the cost estimates from our simple model described above. Although trillion dollar costs are significant, they only have a marginal impact on the overall pattern of global income growth. Since the global economy is expected to be an order of magnitude larger by the end of this century—the prime driver of the increasing carbon emissions—we would still be expected to be some five times richer on a per capita basis than at present almost regardless of the stabilisation target.

The explanation for this result can be understood in the following way: top–down models typically suggest that the cost of a 50% reduction of global $CO_2$ emissions from baseline by 2050 would cost some 1–4% of global GDP, and a 75–90% reduction by 2100 would cost some 3–6% (Grubb et al., 1993; IPCC, 2001c). But since these studies also assume that global income grows by 2–3% per year, this abatement cost would be overtaken after a few years of income growth. Thus, the cost of ‘climate insurance’ amounts to ‘only’ a couple of years delay in achieving very impressive growth in per capita income levels. If the cost by the year 2100 is as high as 6% of global GDP and income growth is 2% per year, then the delay time is 3 years, whereas as the delay time is only 1 year if income grows by 3% per year and the abatement cost is 3% of GDP.

To be ten times richer in 2100 AD versus 2102 AD would hardly be noticed and would likely be politically acceptable as an insurance policy against the spectre of potential ‘dangerous’ climatic changes by most risk averse people.

Once again, all numbers presented here are simply typical of those in the mainstream literature and should not be interpreted as our ‘best guess’ projection; neither do they imply how large the range of costs could actually be. But the overall message appears robust: top-down models of the global energy system suggest that we can stabilise climate with $CO_2$ concentrations well below 500 ppm and still grow the economy by an order of magnitude over this century. Discussions along these lines have been offered by several authors (see e.g. Schneider, 1993; Anderson and Bird, 1992; Grubb et al., 1993; Sterner, 1980, in the context of the Swedish nuclear power debate).

It should also be kept in mind that the environmental benefits of reducing the emissions have not

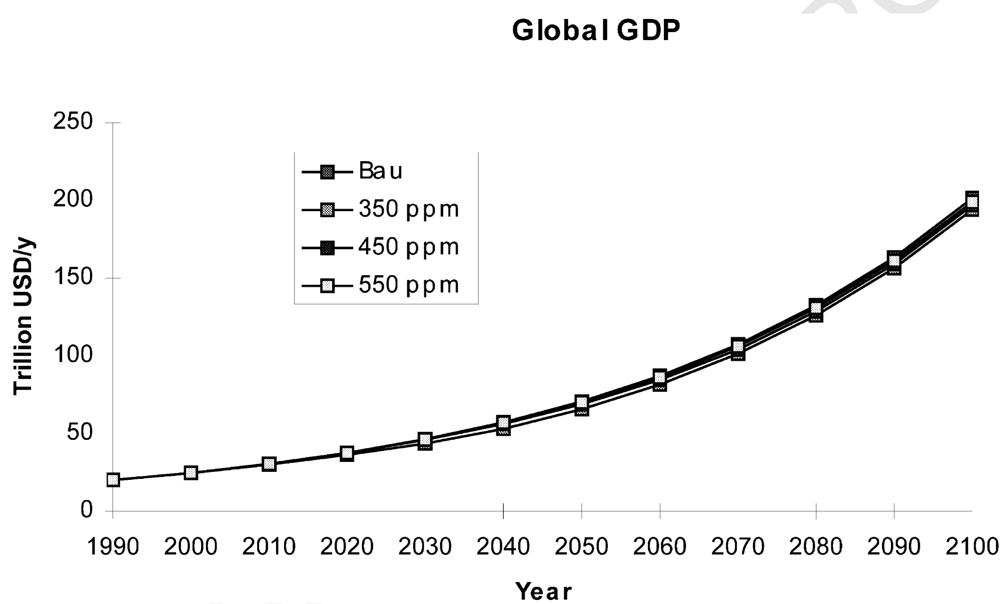


Fig. 1. Global income trajectories under Business as Usual and in the case of stabilising the atmosphere at 350, 450 and 550 ppm. Observe that we have assumed rather pessimistic estimates of the cost of atmospheric stabilisation (average costs to the economy assumed here are $200/tC for 550 ppm target, $300/tC for 450 ppm and $400/tC for 350 ppm) and that the environmental benefits (in terms of climate change and reduction of local air pollution) of meeting various stabilisation targets have not been included.

been included here, so the lines on Fig. 1 are not intended as 'optimal' paths from a cost-benefit analysis. Depending on the values of climate damages assumed, such optimal paths could vary by a very large amount (Azar and Sterner, 1996; Azar, 1998). Furthermore, if the more optimistic views of the bottom–up believers (or those who think endogenous technological growth spurred by climate policies, see Goulder and Schneider, 1999) were considered, then costs would be very much lower than on Fig. 1 and the costs of 'climate insurance' could be only an imperceptible delay in achieving the spectacular per capita economic well being growth levels typically projected in top–down models.

Thus, the way the cost estimates are perceived by the policy community depends critically on the way the cost estimates are presented. Using the perspective in Fig. 1 makes it clear that both top–down and bottom up models find that:

- low stabilisation targets can be met at the same time as the global economy grows several fold over this century (allowing for enormous income growth in both the South and the North);
- the difference in annual average growth rates between a case with an unconstrained use of fossil fuels, and a case with strong restrictions on the use of fossil fuels would likely be less than a tenth of a percent per year over this century.

Similar observations can be made when it comes to meeting near term emissions targets, such as the Kyoto protocol. For instance, if the cost of meeting the Kyoto protocol would be 1% of the Annex 1 countries' GDP (as some rather pessimistic studies suggest, see IPCC, 2001c), it would amount to a reduction in the average growth rate by 0.1% per year over the years 2000–2010. With a growth rate of 2% per year in the absence of carbon abatement, the Kyoto protocol would imply that we would get 20% richer by June 2010 rather than in January 2010. Whether that is a big cost or a small cost is of course a value judgement, but it is difficult to agree with L.B. Lindsey, (2001), President Bush's assistant on economic policy, who states that 'the Kyoto protocol could damage our collective prosperity and, in so doing, actually put our long-term environmental health at risk'.

Finally, all this does not suggest that policies involving global emissions trading and/or carbon taxes would not be needed to achieve large cost reductions nor does it mean that the transition towards a $CO_2$-stabilised energy system below 500 ppm would be easy or will happen by itself. On the contrary, such a transition would require the adoption of strong policies, e.g. carbon taxes, tradable emission rights, regulations on energy efficiency, transfer payments to deal with distributional inequities, enhanced R and D on new energy technologies, etc. There will be winners and losers, and difficult negotiations will be required within and across nations to devise a cost-effective and fair burden sharing of transition costs. But, if further debate leads to the consensus judgement that preventing 'dangerous' anthropogenic climate change implies stabilisation of $CO_2$ concentrations below 500 ppm, then it should no longer be possible to use conventional energy-economy models to dismiss credibly the demand for deeply reduced carbon emissions on the basis that such reductions will not be compatible with overall economic development—let alone to defend strident claims that carbon policies will devastate the economy.

Hopefully, a broader recognition that reduced $CO_2$-emissions will at most only marginally affect economic growth rates by delaying overall economic expansion by only a few years in a century (and that with pessimistic cost assumptions and no benefits for the averted climate changes), will increase the acceptability and willingness amongst politicians to adopt much stricter abatement policies than is currently considered politically feasible.

## 4. Uncited references

Ayres, 1989; Grubb, 1997; Azar and Dowlatabadi, 1999; Hourcade et al., 1996; IPCC, 2001b.

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