Future CO_2 concentrations: Investigating regional greenhouse gas emission reduction strategies

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Abstract The impact of regional reductions in energy related CO_2 emissions on future global concentrations of atmospheric CO_2 is studied using a box-diffusion global carbon cycle model (ANU-BACE). Data for the model runs is based on the mid-range IPCC is92a reference scenario which assumes modest population and economic growth and partial compliance with the Montreal Protocol. Four regions are considered: the OECD; China and Centrally Planned Asia; Eastern Europe and the former USSR; and all remaining nations. An important conclusion is that it will not be possible to stabilise concentrations without a concerted global effort. The model is also used to investigate the level of per capita emissions required to achieve stabilisation at a range of global CO_2 concentrations (350, 450, 550, 650 and 750 ppm) for low, medium and high range population projections. The results are contrasted against the level of global, OECD, non-OECD and selected national per capita emissions corresponding to the IPCC is92a scenario. We find that current projections of future atmospheric CO_2 concentrations assume that the disparity in per capita CO_2 emissions will remain until at least 2100.

1. INTRODUCTION

It has become widely accepted that due to its spatial and temporal extent as well as the size of the population it may potentially impact, climate change presents a significant threat to ecological sustainability. On the political stage, the central debate has shifted in recent times from whether aggressive abatement action is warranted (on the basis of uncertain scientific projections) to questions of equitable burden sharing in terms of emission reduction. For example, a point of primary contention which threatened to disrupt the negotiating process at the first Conference of Parties to the Framework Convention in Climate Change (COP:FCCC) revolved around the familiar North vs. South paradigm. On the one hand, the developing countries were arguing for increased commitments by developed parties. On the other, the industrialised countries, while prepared to accept that their historical emissions are the predominant factor which has precipitated the enhanced greenhouse effect, were unwilling to accept sole responsibility for solving the problem of global warming. Their argument, perhaps based on a perceived threat to current comparative economic advantage, was that increased involvement by developing countries is an essential element of an effective global strategy to counter climate change. They pointed out that in the future, emissions of the large industrializing countries of the South such as Brazil, China and India are projected to escalate. In return, the developing countries countered that economic and industrial growth, and hence increased greenhouse gas emissions, are essential to alleviate poverty, and drew a distinction between "luxury emissions" and "survival emissions"[1]. Furthermore, they pointed out that in per capita terms, their emissions remain significantly less than those of the rich North.

In this article, we attempt to provide a scientific basis for the current political debate on CO_2 emissions reduction through the use of carbon

[1] Ministerial statements to COP:FCCC by Mr Kamal Nath, India's Minister for the Environment and Forests, and Mr H.E. Chen Yaobang, China's Vice Chairman of the State Planning Commission. Outlined in Conference Report; Climate Action Network; 10: April 7 1995

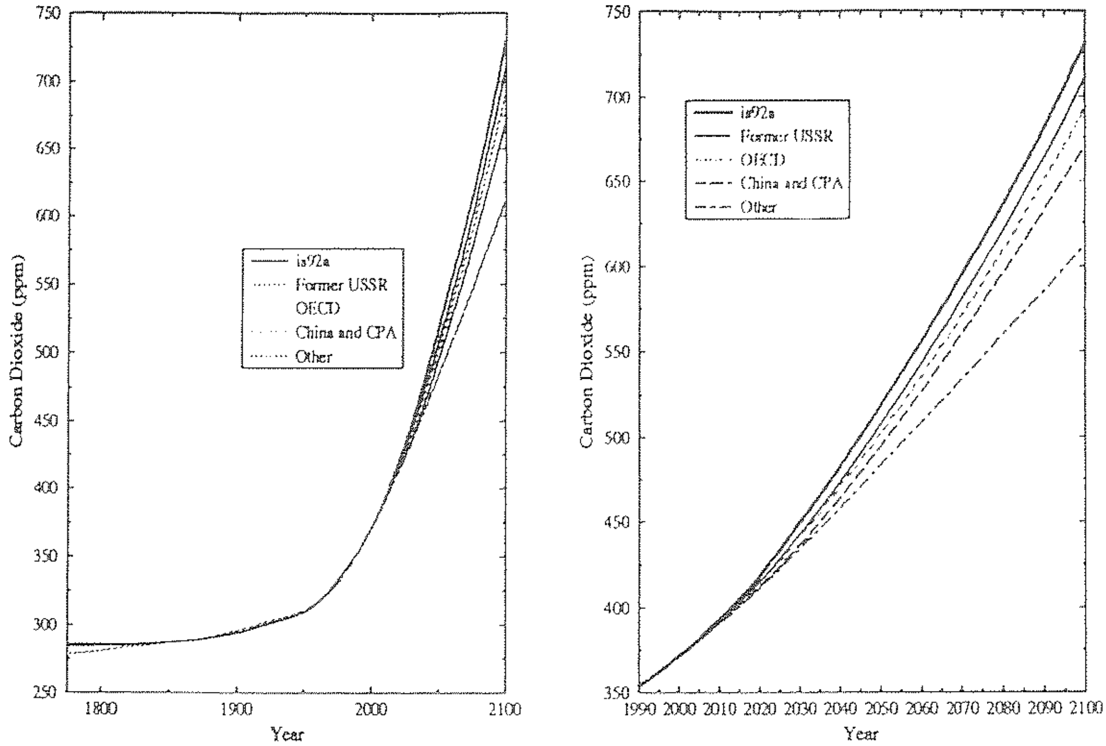

Figure 1: ANU-BACE carbon cycle modelling of regional reductions in energy-related CO_2 emissions by region and their impact on predicted atmospheric CO_2 concentrations.

cycle modelling to quantify the per capita emissions required to achieve stabilisation of atmospheric concentrations of CO_2. Two of the issues central to the debate are addressed: firstly, the North's view that collective action is necessary for an effective solution; and secondly, the issue of a perceived disparity in per capita emissions.

2. RESULTS

The carbon cycle model (ANU-BACE) employed for the purposes of this study is a box-diffusion model with mechanistic CO_2 fertilisation which can be run in both forward and inverse modes. It focuses on the trace gas exchange between the biosphere, the ocean and the atmosphere, and may be used to investigate the relationships between sources and sinks of greenhouse gases and to project their future atmospheric concentrations. The ANU-BACE model was recently included in an intercomparison of carbon cycle models which formed part of the scientific assessment of Working Group I of the Intergovernmental Panel on Climate Change (IPCC)[2]. During that study, the principal sources of uncertainties associated with carbon cycle modelling were identified as budget uncertainty, particularly the estimation of current net flux from land-use change, imprecise calibration and model error, notably the exclusion of feedbacks and the assumption of no residual sink forcing CO_2 fertilisation [Enting et. al., 1994].

Data for the following model runs, unless otherwise stated, was based on the IPCC is92a reference scenario which assumes a population of 11.3 B by 2100, modest economic growth of 2.3 % from 1990-2100, and partial compliance with the Montreal Protocol[3]. The model results are thus dependent on the accuracy and continuing validity of assumptions concerning such factors as oil prices, population growth rates, agricultural markets and technological advancements.

The model is first used in forward mode to study the impact of regional reductions in energy related CO_2 emissions on future global concentrations of atmospheric CO_2. Four regions are considered: the OECD, China and

[2] Details of this modelling exercise are documented in Enting et al. [1994], including the validation and suitability of models.

[3] Further scenario assumptions are outlined in *Emission scenarios for the IPCC: an update: assumptions, methodology and results* [Pepper et. al., 1992].

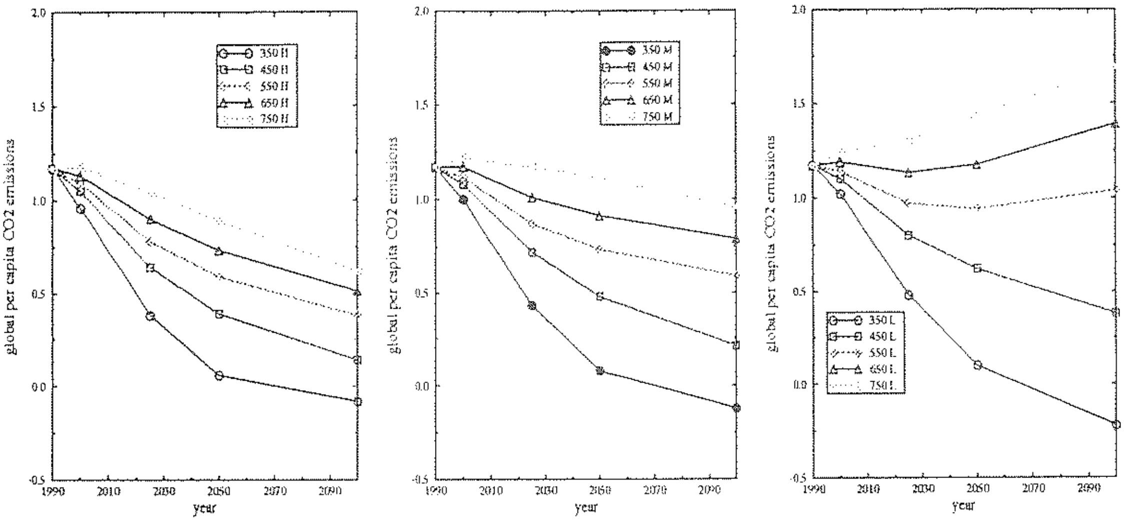

Figure 2: Global per capita CO_2 emissions to stabilise atmospheric CO_2 concentrations at 350, 450, 550, 650 and 750 ppm for high, mid and low range population projections.

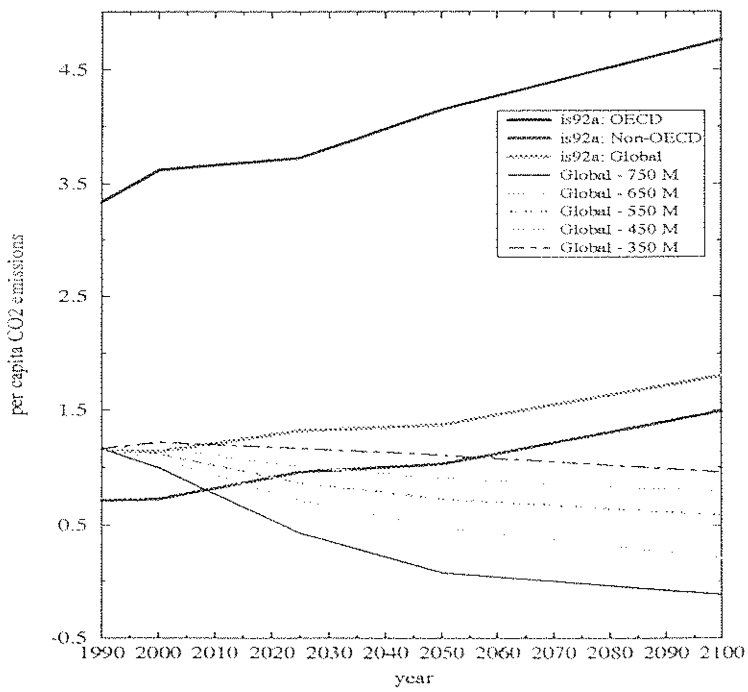

Figure 3: Comparison of global per capita CO_2 emissions required to stabilise at a range of CO_2 concentrations with is92a global, OECD and non-OECD per capita emissions. It should be noted that a broad variation in individual country per capita emissions exists within the OECD and non-OECD groupings.

region	*per capita CO_2 emissions (metric tonnes)*			
	1991	*2100 (is92c)*	*2100 (is92a)*	*2100 (is92f)*
Global	1.18	0.72	1.75	1.47
OECD	3.38	2.39	4.76	4.34
Non-OECD	0.72	0.58	1.49	1.23
USA	5.33	-	-	-
Australia	4.12	-	-	-
Former USSR	3.56	-	-	-
China	0.60	-	-	-
India	0.22	-	-	-

Table 1: Global, OECD, non-OECD and selected national per capita fossil fuel emissions for 1991 compared with projected global, OECD and non-OECD per capita emissions in 2100 for IPCC low (is92c), medium (is92a) and high (is92f) range scenarios.

Centrally Planned Asia (CPA); Eastern Europe and the former USSR; and all remaining nations. Reductions in emissions are calculated assuming regional stabilisation at 1990 levels of energy-related emissions by 2000 and a 20% reduction in emissions after 2000.

Figure 1 presents a superposition of the model results for each scenario. The greatest decrease in emissions from the reference scenario, of 16%, occurs when the "other" nations (including Africa, Latin America and the Middle East) are assumed to reduce their energy related emissions. This corresponds to a lag time of about 25 years between the is92a scenario reaching an atmospheric CO_2 concentration of 613 ppm and the "other" scenario attaining 613 ppm. By contrast, a decrease in CO_2 concentrations of respectively 5.1% and 2.7% occurs for the model runs assuming reductions in emissions by the OECD and the Former USSR/Eastern Europe block of countries. In these latter cases, the lag time is reduced to about 10 and 5 years respectively.

The model is next employed in inverse mode to investigate the level of per capita emissions required to achieve stabilisation at a range of global CO_2 concentrations (350, 450, 550, 650 and 750 ppm) [Taylor, 1995]. Figure 1 presents the results of the modelling for low, medium and high range population projections. In Figure 2, the per capita emissions required to achieve stabilisation for a medium range population projection are contrasted against the global, OECD and non-OECD per capita emissions corresponding to the is92a reference scenario projections. Notably, within sixty years the projected non-OECD per capita CO_2 emission curve will have crossed the curve which traces out the per capita emissions required to achieve stabilisation at 750 ppm, approaching triple pre-industrial levels. It is significant to note that impacts of global warming outlined in the IPCC climate change reports have been projected according to a scenario in which atmospheric concentrations of CO_2 have been doubled from pre-industrial levels.

In Table 1, the global, OECD and non-OECD per capita CO_2 emissions for 1991 are compared with selected national emissions for the same period, and contrasted against projections of per capita emissions in 2100. During 1991, the United States had the highest per capita emissions at 5.33 metric tonnes, while China's per capita emissions for the same period were 0.60 metric tonnes. According to low (is92c), medium (is92a) and high (is92f) range scenarios, the current disparity between OECD and non-OECD per capita emissions is projected to continue through to the end of the next century.

3. CONCLUSIONS AND DISCUSSION

Assuming society chooses to honour the commitments of the United Nations Framework Convention on Climate Change, and hence uphold the notions of sustainable development, intergenerational equity and the precautionary principle[4], active mitigation of global warming becomes imperative. Under this rationale, each nation must seek to achieve an optimal reduction

[4] Principles of the United Nations Framework Convention on Climate Change 1992

in greenhouse emissions within economic, social and cultural constraints. If we recognise that the developing nations and island states are the most vulnerable populations to severe impacts of global warming [IPCC, 1992], and that the cause of this threat is directly linked to the historical economic advancement of the developed countries, then it may indeed be argued that the developed countries, including Australia, have an international responsibility to make firmer commitments to reducing emissions. However, as indicated by the preliminary ANU-BACE carbon cycle modelling results, no individual region can singlehandedly control or radically alter the course of global increases in CO_2 emissions. This is primarily due to the majoritive share of global CO_2 emissions shifting over time from the OECD to the non-OECD countries as a result of large projected population growth in the developing countries. Accordingly, a collective effort will eventually be necessary in order to achieve stabilisation of atmospheric CO_2 concentrations. The authors propose that this effort should focus on setting a per capita CO_2 emissions cap, consistent with achieving CO_2 stabilisation, which will guide in the formulation of targets and goals.

Accepting that a concerted global effort is pivotal to addressing climate change effectively, the task then becomes one of determining equitable burden sharing and an appropriate timeframe in which to extend developing countries' commitments. The emissions cap suggested previously provides one means by which to formalise the necessity of developing countries' participation. It would provide the non-OECD countries with a window of opportunity in terms of continued development while acknowledging the undesirability of an infinite increase in non-OECD emissions. However, whilst recognising the greater role that developing countries will be required to play over the coming decades, it is important to be aware of the significant disparity in per capita CO_2 emissions between developed and developing country parties, as the latter modelling illustrates. A range of IPCC scenarios (is92a,c,f) incorporating differing population growth assumptions all project that this disparity will continue through to 2100. On equity grounds, this suggests that the OECD should act immediately to reduce their per capita greenhouse gas emissions towards equitable and sustainable levels.

It is significant to note that considerable uncertainty remains concerning the magnitude and timeframe of climate change, as well as the accuracy of scientific, economic and demographic projections. As the sophistication of carbon cycle models develops, and subtle feedbacks are better integrated, it will be possible to quantify more definitively the impacts of regional CO_2 emissions reduction on atmospheric CO_2 concentrations.

4. REFERENCES

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