## Conference on

# Global Carbon Budgets and Equity in Climate Change

## 28-29 June 2010

### Discussion Paper, Supplementary Notes and Summary Report



Organised by:
**Tata Institute of Social Sciences**
Mumbai

Supported by:
**Ministry of Environment & Forests**
Government of India


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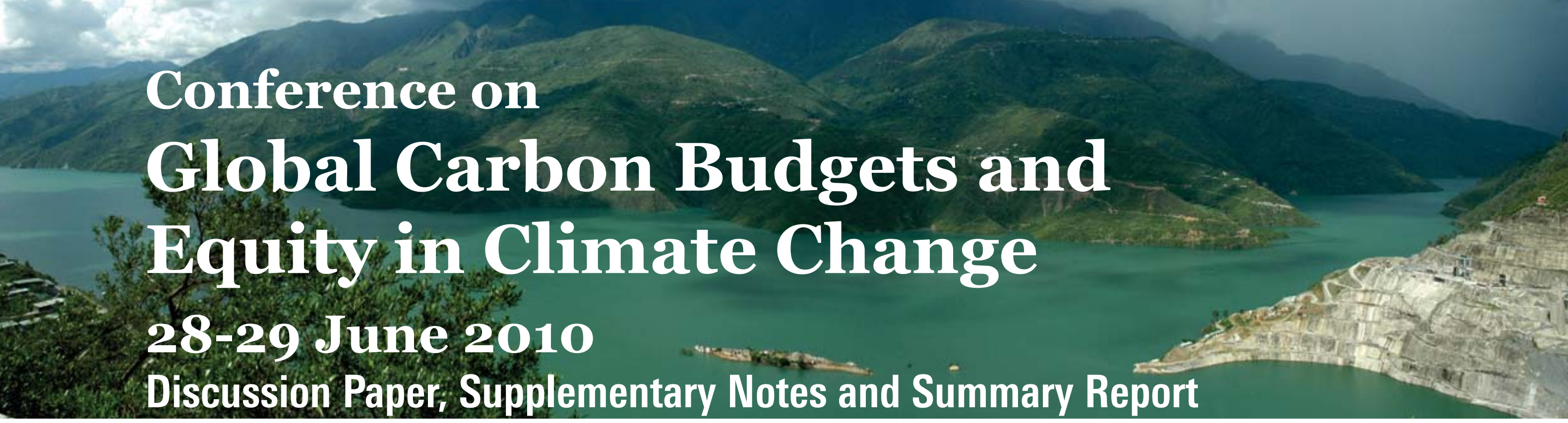

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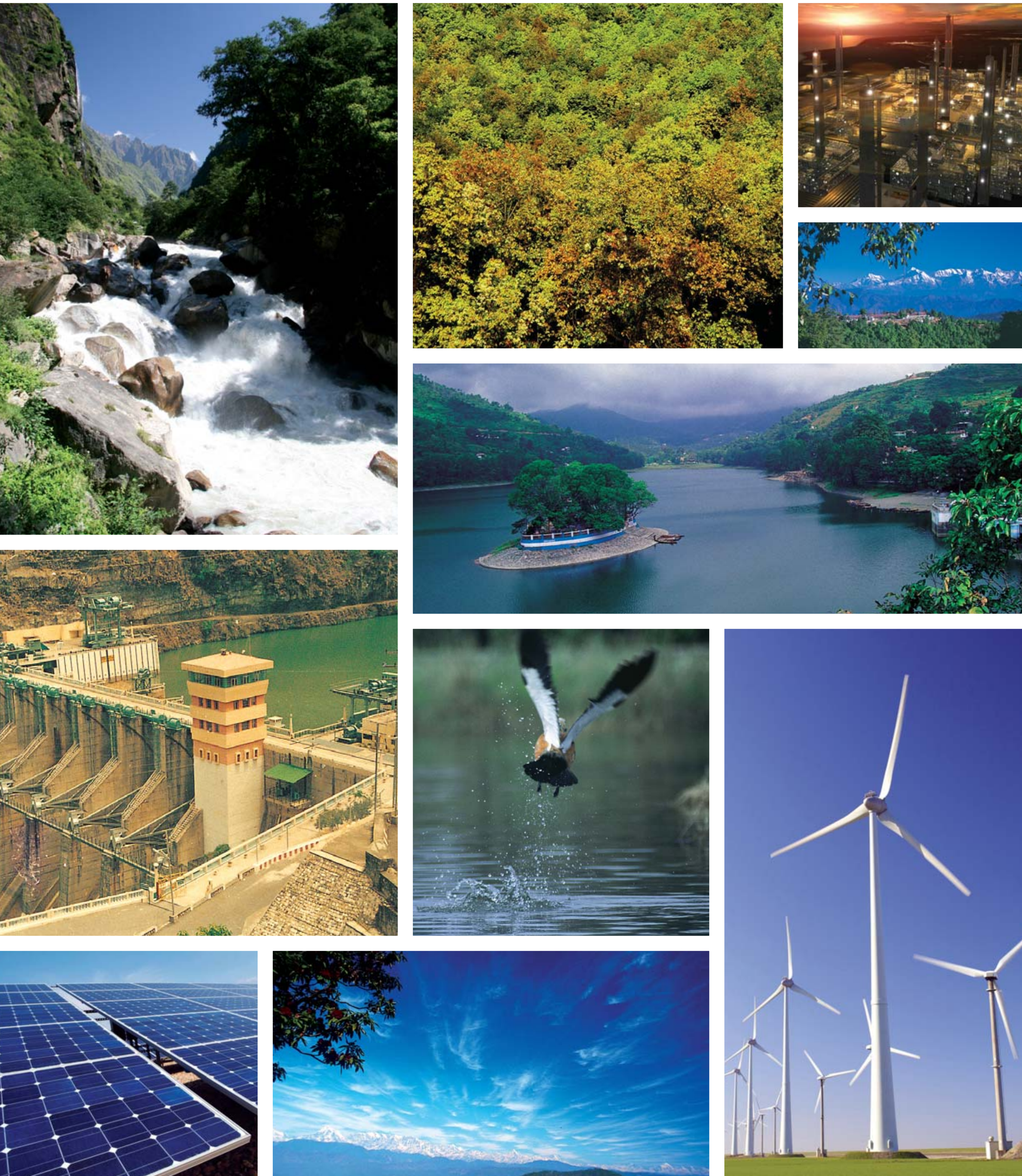


# Contents

# Message from the Minister

I am pleased to introduce the proceedings of the Conference on "Global Carbon Budgets and Equity in Climate Change" that was hosted by Tata Institute of Social Sciences (TISS), Mumbai, India, on June 28-29, 2010, which I had the pleasure of attending.

This conference was a landmark, in that it brought under one roof, various ideas and proposals on equity in climate change, especially those relating to carbon budgets. We had participants from Germany, UK, Brazil and Malaysia, and I think we made great progress in sharing understanding of various proposals.

Equity is embodied as the very first principle in the United Nations Framework Convention on Climate Change, in Article 3, where it is stated: *The Parties should protect the climate system for the benefit of present and future generations of humankind*, **on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities.**

In recent times, the issue of equity seems to be sliding out of the mainstream of the climate negotiations discourse. This is unfortunate. I am glad that this conference has played a major role in bringing the issue of equity, equitable access to the carbon space / equitable burden sharing, back into the mainstream.

**It is critical to emphasise here that now that the world has broadly agreed to a "global goal" of limiting temperature increase to 2 degrees Celsius, we need to move from the concept of equity per se to a more specific articulation of it. In particular, the concept of equitable access to atmospheric space has to now be a primary focus of the climate change negotiations.** Any discussion on a global goal – whether for limiting temperature increase or emissions reduction – is incomplete, meaningless and impossible in the absence of such a paradigm. There is no substitute for the equitable access paradigm. Unilateral pledges, for example, do not and cannot substitute for this paradigm.

**It is therefore vital that the equitable access paradigm is operationalised and spelt out in practical terms.** Carbon space is development space and therefore we must agree on an appropriate methodology to determine carbon space that has been used up and that can be used in future, the rights and allocations for this space between developed and developing countries, including the implications for finance and technology transfers to developing countries.

Some scholars have also suggested that, in addition to equitable per capita entitlement, the level of development of a country is important in determining a country's emissions entitlement. A country with low per capita income, with little infrastructure, few climate-friendly technologies and little organisational capacity requires a higher per capita emissions entitlement compared to a developed country with well developed infrastructure, technology and capacity. Thus the carbon space concept also means that poorer countries need more carbon space in order to achieve the same level of per capita income as richer countries.

**The carbon budgets approach, made explicit by think tanks in Germany, UK, Brazil, China, India and other countries as well as the South Centre, Geneva, provides a useful basis for conceptualising and operationalising equity.** The BASIC countries are meeting in Rio de Janeiro in late-July and we have set aside a day to have a technical workshop on equity related issues. After the workshop in Rio, the BASIC and other developing countries would like to bring the discussion on equitable access to the other members in the UNFCCC, with the aim of mainstreaming it in the negotiations. I am hopeful that we can make tangible progress on this by Cancun and in Cancun, ensuring that Cancun becomes an equity based conference.

I congratulate the organisers of this Conference, and thank them for inviting me to be part of it. I also thank the delegates, especially those who came from afar, for participating in an event of such substantial import.

**Jairam Ramesh**
Minister of State for Environment & Forests
(Independent Charge), Government of India

# Global Carbon Budgets and Burden Sharing in Mitigation Actions – Summary for Policy Makers

Tejal Kanitkar*
T. Jayaraman*
Mario D'Souza*
Mukul Sanwan**
Prabir Purkayastha***
Rajbans Talwar***
D. Raghunandan****

*Centre for Science, Technology and Society, School of Habitat Studies, Tata Institute of Social Sciences, Mumbai, India
**Formerly Policy Advisor, UNFCCC (1995-2007)
***Delhi Science Forum, New Delhi
****Center for Technology and Development, New Delhi

Address for Correspondence: **Center for Science Technology and Society, Tata Institute of Social Sciences, Deonar, Mumbai 400088, Tel: 022-2552 5372, Email: tjayaraman@tiss.edu**

# Global Carbon Budgets and Burden Sharing in Mitigation Actions – Summary for Policy Makers

## 1. Introduction

The development of a simple, straightforward method to deal with the question of burden-sharing in mitigation continues to be the key challenge in global climate governance. It is increasingly evident that the difficulty in resolving this question lies in the dual character of greenhouse gas emissions, especially carbon dioxide. While on the one hand such emissions are the cause of global warming, it is also clear that for developing countries in the short and medium term, carbon dioxide emissions continue to be a necessary part of growth and development. This is a consequence of the continued dependence on fossil fuels that will persist until alternative technologies become techno-economically viable for the bulk of developing countries whose per capita emissions and per capita GDP are well below the global average, on a scale suitable for large-scale deployment in these countries.

From this point of view, it is clear that carbon dioxide emissions are to be treated as the utilization of the global ``carbon space'' available in the global atmospheric commons, and should not be seen only in terms of the environmental damage that they can cause. The total carbon space available is limited since human society cannot allow the cumulative emissions, or the stock, of carbon dioxide in the atmosphere to exceed a fixed amount without giving rise to impacts that will have profoundly negative consequences for human well-being.

The fair and equitable utilization of this carbon space thus imposes a common responsibility on all nations. Since the available carbon space is part of the global atmospheric commons it is evident that every nation's fair share of carbon space or carbon space entitlement is proportional to its share of the global population. From this perspective, no nation can lay claim to more than its fair share, and the burden of mitigation will fall progressively on all nations as they approach their fair share of global carbon space.

The crucial global climate policy issue today is the current over-occupation of carbon space by the developed nations whose historical emissions have given them far more than their fair share of carbon space. This has two critical consequences. The first is the implications of this over-occupation by the developed nations for the carbon space entitlement of developing nations. Within a fixed global carbon budget, preserving the carbon space entitlements of developing nations implies negative entitlements for the developed nations in the future.

But a second, equally important, issue is the availability of physical carbon space for the developing countries in the future. Since the carbon dioxide that is already in the atmosphere cannot be readily removed, it becomes difficult to determine the manner in which an equitable partitioning of the available physical carbon space can be achieved, and in particular how developing nations can come close to achieving their entitlement in physical terms. We also need to undertake this reallocation of carbon space dynamically since all nations have varying rates of current annual emissions as well as varying rates of emissions growth. This dynamic reallocation of physical carbon space has to be achieved while ensuring that the sum total of emissions by all nations stays within the global limit in order to keep the rise in temperatures within acceptable limits.

## 2. A Dynamical Carbon Space Model

To explore these two issues, we first develop, in this paper, a ``dynamical'' carbon space model for generating different scenarios of the partitioning of global physical carbon space over specified time periods. These scenarios may be generated by varying a limited number of parameters in the model. In the second part we also evaluate different indicative strategies for a more equitable distribution of physical carbon space to be achieved by the middle of this century. The paper indicates how this may be done while recognizing the carbon space needs of all developing countries, especially the Least Developed Nations (LDCs) and those nations with per capita emissions and GDP well below the global average. While doing so, we also use the model to indicate the manner in which the acceptability of such strategies as a basis for cooperation between nations can be strengthened. This is done based on a careful evaluation of the current occupation of carbon space by different nations and the various scenarios for future allocations generated by the model.

**The model has the following features:**

i) Computation of the current share of physical carbon space compared to fair share for various regions/nations;

ii) A total carbon space budget which is the global constraint;

iii) Emission cuts for nations which are above their fair share;

iv) Allowing growth for nations which are below their fair share and

v) Determining the quantum of emissions reductions or emissions growth for regions/nations based on the global constraint and the extent to which their current occupation of carbon space is above or below fair share.

In the actual computations the basic equity target that is sought to be implemented is the right of nations to attain a fair share to carbon space at the latest by 2050. We also add the rule that once a nation or region is on track to obtain this fair share, then emissions reduction may begin without waiting for the fair share to be achieved first. We disallow overshooting the fair share.

We fix the global carbon space budget to be 1440 Gt of carbon dioxide between the years 2000-2050 (393 Gt of carbon). Following Meinshausen et al.[6], we note that a carbon budget of 393 Gt of carbon gives a probability between 29% and 70% of exceeding a 2 deg C rise in temperature. Since emissions from 2000 to 2009 amount to approximately 93 Gt of carbon (including LUCF emissions), it is the remaining amount that is available from 2010 to 2050. We note that it is increasingly unlikely that a budget significantly lower than 393 Gt of carbon for 2000-2050 will be adhered to. Hence in the calculations presented in this paper we will work with a budget of 393 Gt of carbon for the first half of the 21st century.

We note that the carbon space perspective provides a much more sound approach to specifying mitigation action at the global and national level, compared to the conventional method of first specifying only peaking years and/or specifying the annual emissions reduction to be achieved in some milestone year towards mid-century. In the carbon space perspective it is the cumulative contribution to current stock that is the key to determining fair share and not just current flows. Viewed in technical terms, it is the entire area under the emissions trajectory curve that is of significance and not just the value of annual emissions specified along the curve at one or two points. Indeed all global mitigation proposals can be viewed in the ultimate analysis as proposals for the allocation of carbon space, thus providing an unambiguous basis for evaluating the true import of these proposals, particularly for developing countries. It also provides a basis for comparing the adequacy of national mitigation actions.

We emphasize that the considerations of this paper are not intended to provide an explicit position for current climate negotiations, though they may help evaluate concrete elements of alternative strategies. The first key aim of this paper is to provide a model based on a sound analytical framework utilising which different mitigation proposals may be evaluated and compared, while foregrounding considerations of global equity. The second key aim of this paper is to provide scenarios for achieving globally equitable outcomes while determining the differentiated responsibilities of various players in achieving these outcomes.

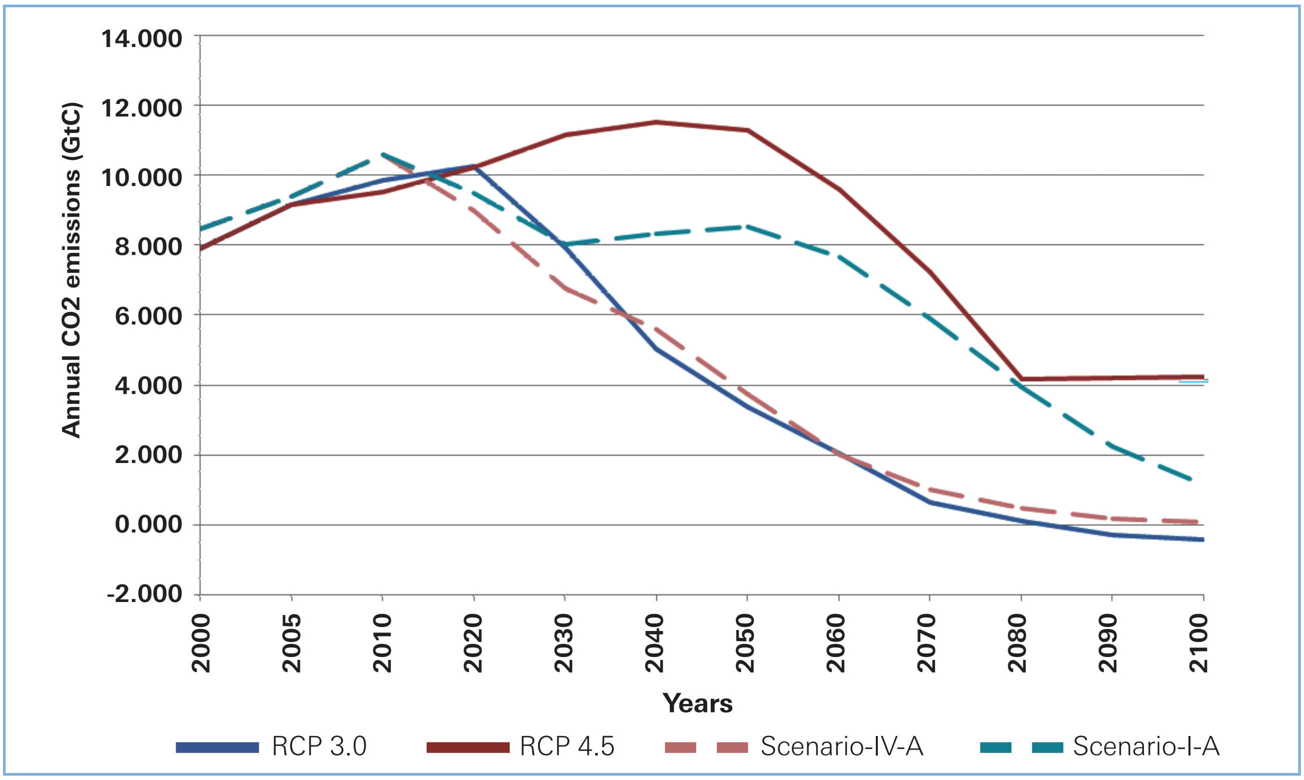
In what follows we use the term entitlements to refer to the amount of carbon space to which regions/nations have a right. We use the term physical carbon space or physical carbon budget in its obvious meaning. If a nation emits more than its fair share thus over-occupying the global commons in a given time period, then it would have negative entitlements until its cumulative emissions come back to its fair share later. Zero entitlements or close-to-zero entitlements at any given time imply that a region/nation is at its fair share or close to its fair share respectively.

## 3. Key Findings

**(a) We demonstrate in this paper that a significantly more equitable distribution of carbon space by 2050 is not a runaway scenario.** With the model of equity described above (viz. attaining fair share by 2050), we demonstrate that, even without the global carbon space constraint, the global emissions trajectory is not an indefinite rise in emissions. With absolute reduction in emissions by all nations after 2040, the global emissions trajectory is below that of the IPCC's Representative Concentration Pathway 4.5, which is one of the moderate scenarios for the IPCC's Fifth Assessment Report. Without this restriction the emissions trajectory is higher. However these trajectories give rise to unacceptable global budgets with a mean probability of 50% or above for a 2 deg C rise in temperatures. Physical carbon budget constraints are therefore essential.

Figure 1

**Comparison of TISS-DSF Model (Scenarios –I-A and IV-A, Base Year -1850) and Representative Concentration Pathways**




***Scenario-IA:*** *There is no global budget constraint. Countries above fair share have to cut their emissions while those below their fair share are allowed to increase emissions.(The rate of increase in emissions reduces post 2020).*

***Scenario-IVA:*** *The rules implemented in Scenario-IA are implemented here within a global budget of 300 GtC between 2010 and 2050. There is also a penalty for countries with per capita emissions above specified thresholds.*

**Table 1 Comparison between RCPs and Scenarios I and IV**

| | CO2 concentration in 2100 (ppm) | Temperature rise in 2100 relative to 1765 (°C) | Probability for exceeding 2 °C | |
|---|---|---|---|---|
| | | | Illustrative result | Range |
| RCP 3 | 403.2 | 1.65 | | |
| RCP 4.5 | 524.6 | 2.37 | | |
| Scenario I-A | 468.6 | 2.06 | 64% | 41% to 81% |
| Scenario IV-A | 406.2 | 1.66 | 49% | 28% to 68% |

(b) With 1850 as the base year for accounting for responsibility for emissions we find that the extent of over-occupation of carbon space by the developed nations is such that they will have only negative entitlements to carbon space in absolute and relative terms until 2050 and beyond. This implies that despite any scheme of the redistribution of physical carbon space, especially after accounting for a global carbon budget, developing countries will not realize their full entitlement by 2050. The bulk of developing countries will fall short of their entitlement.

**Table II. Total and Current Entitlements for Each Country/Region (1850 Basis)**

| 1850 Basis | Total Entitlement between 1850-2050 (Based on 2009 Population and a 300 GtC Carbon Budget between 2010-2050) | Current Contribution to Carbon Stock (1850-2009) | Total Entitlements (2009 onwards) |
|---|---|---|---|
| | GtC | GtC | GtC |
| Annex-I | 117.99 | 245.34 | -127.36 |
| China | 123.69 | 33.09 | 90.60 |
| India | 110.00 | 8.66 | 101.33 |
| Rest of the World | 280.32 | 44.90 | 235.42 |

(c) We examine the consequences of the alternate choice of base year as 1970. In the carbon space approach, using 1850 as the basis year from which emissions are accounted for, the developing countries are entitled to an overwhelming share of the carbon space available in the future beyond 2010. Our analysis shows that using 1970 as the basis year also gives a similar result, with developing countries still being entitled to the bulk of the carbon space in the future. This is because the Annex-I countries' continued over-occupation in absolute terms of the total bulk of carbon space has occurred in the period 1970-2009. Accounting only for non-LULUCF emissions, the total gross carbon dioxide stock contributed from 1850-2009 is approximately 332 Gt of C of which only 109 Gt were contributed from 1850-1970. Thus the 1970-2009 contribution to gross stock accounts for the greater share (67.2%) of post-1850 emissions, amounting to 223 Gt of C. In terms of entitlements the developed countries would have again only negative entitlements even in the 1970 basis.

1850 and 1970 are both useful benchmark years to consider. 1850 is conventionally used, as the benchmark base year in discussions of the historical responsibility of developed countries for global warming as it signals the advent of the industrial revolution. 1970 is significant because monitoring of carbon dioxide emissions was fully recognized by the year 1972 in the Stockholm conference on the Human Environment organized by the United Nations. We also note that prior to this conference, in 1968, the problem of global warming due to carbon dioxide emissions had been noted at a conference organised by the American Association for the Advancement of Science, expressly conducted in preparation for the 1972 conference[1] . The recently released documents from the Moynihan correspondence[2] during the Nixon administration also demonstrate clearly that the problem of global warming was fully known at the highest levels of the political leadership of the United States. It bears emphasis that at the time global warming was considered a threat by the Nixon administration, since the preliminary assessments of that era tended to have higher damage assessments within shorter time scales compared to subsequent studies.

| Table III. Fair and Actual Shares of Carbon Space | | | |
|---|---|---|---|
| **Countries/Regions** | **Fair share of Carbon Space** | **Current Actual Share of Carbon Space** | **Current Actual Share of Carbon Space** |
| | **(Based on 2009 pop.)** | **(1850 basis)** | **(1970 basis)** |
| USA | 5% | 29% | 24% |
| Other Annex-I | 14% | 45% | 41% |
| China | 20% | 10% | 13% |
| India | 17% | 3% | 3% |
| Other Emerging Economies | 15% | 9% | 12% |
| Rest of the World | 29% | 4% | 5% |

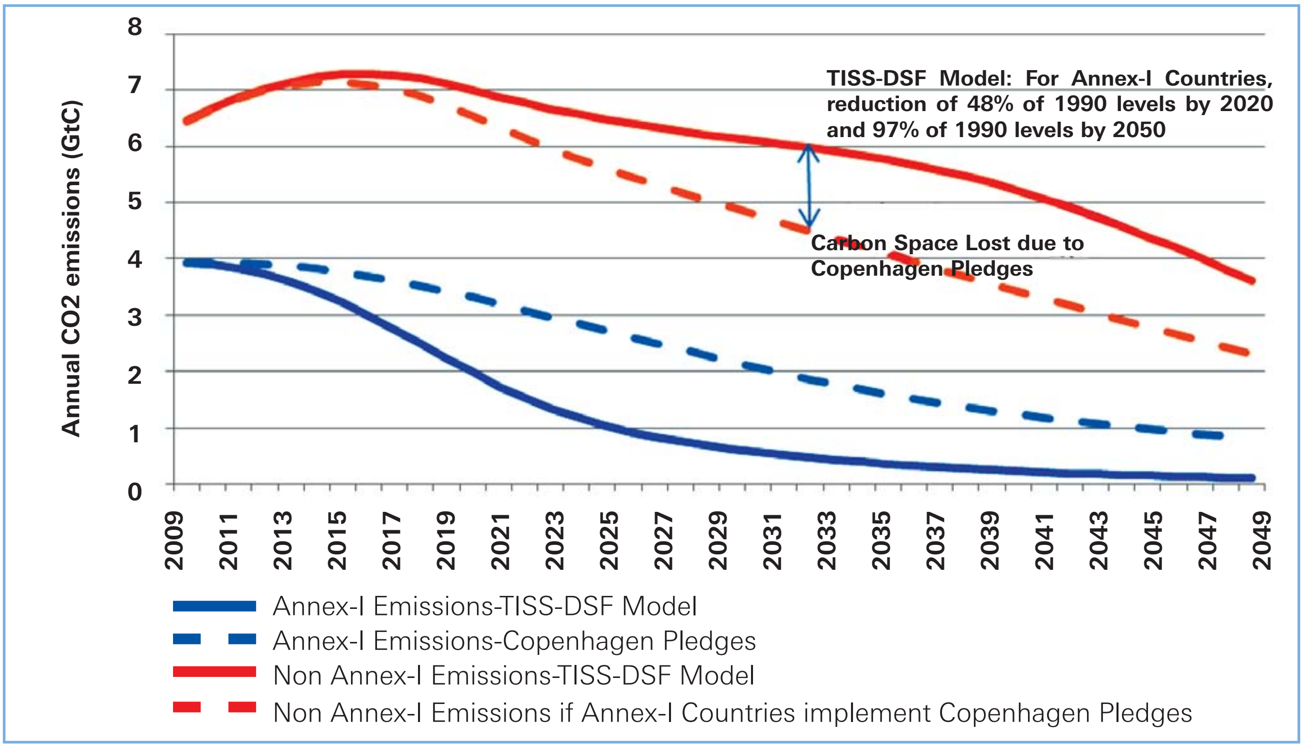
| Table IV. Total and Current Entitlements for Each Country/Region (1970 Basis) | | | |
|---|---|---|---|
| **1970 Basis** | **Total Entitlement between 1970-2050 (Based on 2009 Population and a 300 GtC Carbon Budget between 2010-2050)** | **Current Contribution to Historical Carbon Stock (1970-2009)** | **Total Entitlements (2009 onwards)** |
| | **GtC** | **GtC** | **GtC** |
| Annex-I | 117.99 | 218.37 | -100.38 |
| China | 123.69 | 44.72 | 78.97 |
| India | 110.00 | 10.83 | 99.17 |
| Rest of the World | 280.32 | 58.08 | 222.24 |

(d) We find that the bulk of the developing world will obtain little physical carbon space, let alone equity, within even a 393 GtC budget, unless the developed countries, particularly the United States, make sharp and immediate cuts in their emissions. The Copenhagen pledges by the Annex-I countries, together with a 80% reduction below 1990 levels by 2050, constitutes a further sizeable appropriation of carbon space by the Annex-I countries.

Figure 2

## Comparison of TISS-DSF Model with Copenhagen Pledges

Emission Trajectories for Annex-I and Non-Annex-I Countries - Comparison between TISS-DSF Model and Copenhagen Pledges




(e) Some individual developing countries will also need to implement emissions reduction from business-as-usual and later absolute reduction of emissions, since there is a limit to the quantum of physical carbon space that can be re-allocated from the developed countries to the developing countries. This restriction however is imposed as it becomes clear that these countries will nevertheless be on course to reach their fair share of carbon space by 2050

(f) With a base year of 1970, we show that India and the bulk of the developing countries can indeed reach much closer to their fair share of carbon space by 2050. This is in sharp contrast to earlier considerations where it appeared that the share of carbon space of India and these other nations' would hardly improve from the current situation by even mid-century. The 1970 base year choice benefits the 'late-starter' developing countries relative to the developing countries that have had steep growth trajectories over the last 30-40 years. The latter will obtain physical carbon space that is much closer to their entitlement of carbon space by 2050. However some developing nations with currently very low rates of emissions growth will not reach fair share even by 2050, but may improve their share post-2050.

(g) In these indicative scenarios, India's per capita emissions, computed using population projections for the future, do not in 2030 cross the outer limit estimated in the studies acknowledged by the Ministry of Environment and Forests, Government of India. However India will have this corresponding carbon space only if the developed countries cut their emissions sharply. The implications of equity based on per capita carbon budgets are in general different from those of equity based on per capita flows of emissions. Based on current emissions efficiency of energy use, India's emissions in 2030 are likely to correspond to energy use per capita that is comparable to mid-level developed countries that have relatively lower per capita energy use levels.

(h) Overall we find that, given the limitations on the actual physical carbon space that can be redistributed from the developed countries; there is an issue of physical carbon space allocation among Third World nations that needs to be resolved adequately.

(i) The dynamical emissions model reported in this paper also provides a method of producing several equity-based benchmark scenarios by the variation of appropriate parameters of the model.

(j) We also simulate the effects of specific emission reduction or carbon budget proposals and compare them to our model predictions. We are thus able to compare a range of other proposals.

Figure 3

**Fair Share, Current Share and Future Share (Under Scenario-IV) of Carbon Space (1850 Basis and 1970 Basis)**

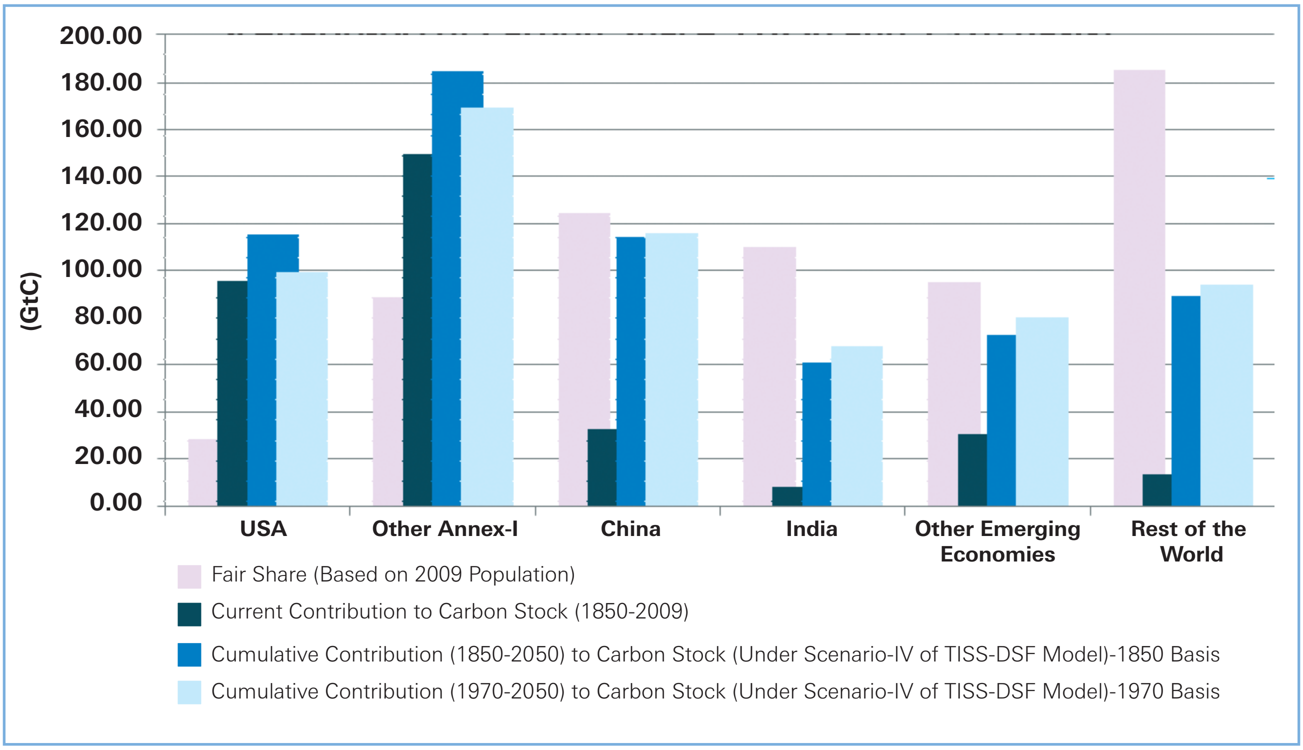


Figure 4

**Comparison of Proposals for USA**

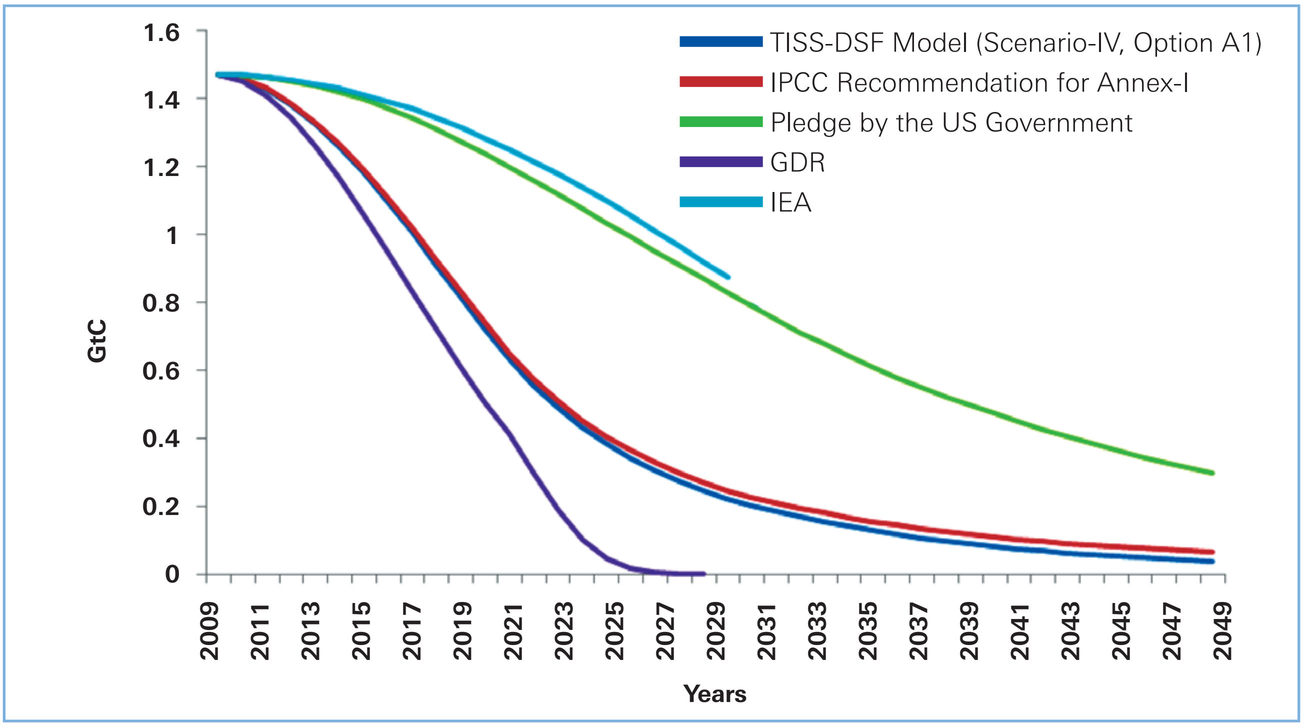
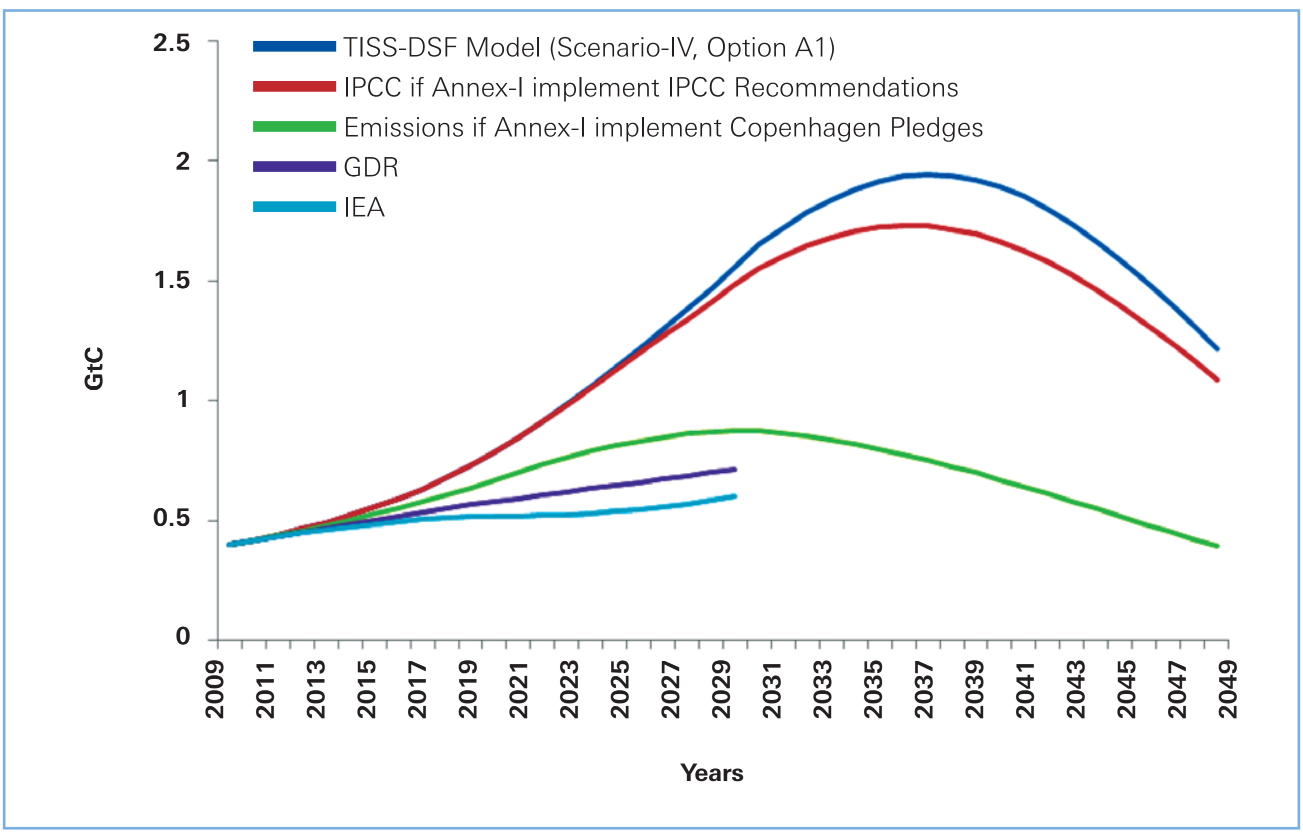



Figure 5

**Comparison of Proposals for INDIA**



## 4. Further Observations and Comments:

(a) Our results show that all questions of the distribution of carbon space amongst the developing countries are in the first instance a consequence of the over-occupation of carbon space by the developed nations. The realization of this fact is the key to avoiding South-South conflict in climate policy-making. Our results imply that no negotiating position based on the considerations of this paper can bypass the requirement of sharp and immediate cuts by the developed countries as a primary condition for further action.

(b) We note that we study 1970 as a base year mainly for the purpose of computing the shares of each region/nation to the total physical stock of carbon dioxide emissions. However a different base year such as 1850 may still be used in negotiations on issues such as financial transfers from developed to developing nations in a climate justice perspective. The negative entitlements that accrue to the developed countries provides a natural basis for considerations of the quantum of financial transfers and the extent of technological transfers from the global North to the South, apart from the claims of the South on the question of adaptation.

(c) In this model, we use the population of various nations/regions in 2009 as the basis for calculation of the fair share of global carbon space for these region/nations. However we note that recognizing this as part of the principles of burden-sharing will be a major concession on the part of several developing countries. Whether they would accept such a position will undoubtedly be the subject of domestic discussion and international negotiations. However it may also be noted that using moving population figures for computing carbon space entitlements works to the disadvantage of several emerging economies, whose populations are likely to stabilize sooner than other developing nations.

(d) The physical carbon space available to India in this model (though substantially higher than in many other mitigation proposals) is not tantamount to unrestrained emissions growth but reaches only per capita energy use (at current rates of emissions efficiency of energy use ) that is comparable to high-HDI low-per capita energy use countries in the middle range of developed countries.

(e) We emphasize that the within the carbon budget there is considerable scope for national autonomy in decision-making in determining the emissions trajectory of individual nations. Once the physical share of these countries in the global carbon budget is established it is open to them to reshape their real emissions trajectories in accordance with their national circumstances, provided they stay within their share of global carbon space by 2050. Thus developing countries will have flexibility in timing their peaking years and the reduction in emissions to be specified in milestone years, and need not all follow identical trends. This flexibility is lower for relatively high emitters among the developing nations.

(f) In addition, research, development and transfer of innovative technologies at affordable cost will also play a key role in keeping emissions trajectories within the limits of available carbon space and are clearly an integral part of the negotiations in developing a vision for climate change mitigation based on common but differentiated responsibilities. This is evident from the fact that the majority of developing countries will fall short of their entitlement even by 2050.

But it is worth re-emphasising that in the carbon space perspective the focus shifts decisively towards underlining what all nations need to do to guarantee human well-being on the global scale as well as intergenerational equity, rather than rendering such considerations secondary to the assumptions of business-as-usual economic perspectives.

# Leadership In The Climate Negotiations:

## The Shared Vision Requires A New Sustainable Development Framework And National Carbon Budgets

**Mukul Sanwal***

As future increases in global emissions of carbon dioxide are going to come from developing countries, they must not only be innovative in modifying growth pathways but also take the lead in developing a new sustainable development framework for the climate negotiations.

A developing country led strategic initiative in the climate negotiations must safeguard the ecological health of the planet and ensure policy space for developing countries to grow and focus on the transformation of the world economy and human activity, as decisions taken now will shape options in the coming decades.

The BASIC ministers' call, at their meeting in May, for a "step change" in the climate negotiations was long overdue. They have rightly stressed that equity will have to be central, based on an analysis of the remaining global carbon budget that will allow developing countries equitable space for economic growth. Patterns of resource use have to be common for all countries.

A new agenda is needed because the global goal of keeping increase in temperatures to below 2 degrees Celsius requires 14 Giga tonnes (Gt.) of emissions abatement by 2020, whereas the firm pledges made after the Copenhagen Conference amount to only around 9 Gt, with developing countries contributing more than the reduction commitments of the developed countries. Moreover, the countries with per-capita emissions and incomes below the global average, and this includes India, collectively would need at least as much carbon budget as the developed countries are about to take up from now until 2050, if they were to merely reach average global greenhouse gas emissions of 4 tonnes per capita by 2050, that is recognized as a legitimate aspiration in the Copenhagen Accord.

Consequently, the climate negotiations must recognize that both global temperature and greenhouse gas concentration targets are needed as the basis for long term co-operation to meet the climate challenge. A report of the National Academy of Sciences of the United States, on limiting the magnitude of future climate change, published in May 2010, also concludes that the "policy goal must be stated as a quantitative limit on domestic GHG emissions over a specified time period – in other words a GHG emissions budget ….. national shares of global emissions need to be agreed at the multilateral level as the basis for developing and assessing domestic strategies". The United Kingdom also has legislation establishing a national carbon budget.

Developed countries continue to press for legal recognition of their aggregate reductions, and current proposals give them more than two times the per capita share of developing countries in 2050. Post Copenhagen, emissions of GHGs' cannot be seen only in terms of environmental damage, as they also have a development dimension, and global policy requires allocation criteria directly linked to outcomes that can be measured.

The key global climate policy – or equity - issue is that without developed countries sharply reducing their emissions immediately other countries cannot get their fair share of the carbon space for economic growth, if the global goal of limiting rise in global temperature to 2 degrees Celsius is to be met. Since the available carbon space is part of the global atmospheric commons, every country's fair share of carbon space is proportional to its share of the global population.

As climate change is caused by the cumulative stock of emissions and not just present or future flows, considering cumulative emissions provides a much

* **Mukul Sanwal** has held senior policy positions in the Government of India, United Nations Environment Programme and in the UN Climate Convention (UNFCCC) Secretariat. These are his personal views

more scientific approach to specifying mitigation action at the global and national level, compared to the current method of first determining peaking years and/or specifying the annual emissions reduction to be achieved in some milestone year towards mid-century. It also provides a better basis for comparing the adequacy of national mitigation actions.

A carbon budget based approach enables a review of long held developing country positions that have been seen as hindering progress in the multilateral negotiations. Developed country overuse of the carbon space, or two-thirds of their cumulative emissions, has occurred after 1970, and such emissions should be considered as their current, rather than historical, responsibility for causing the global problem. Climate change came onto the global agenda in the UN Conference on the Human Environment held in Stockholm, in 1972.

Even after ignoring historical emissions, the allocation of the remaining carbon space can be made to developing countries so as to ensure their fair share of carbon space by 2050, enabled and supported by development and transfer of innovative technology. More specificity can also be provided to the allocation criteria by limiting future energy use per capita to that of mid-level developed countries. The new agenda would reflect the greater responsibility developing countries are prepared to take in accordance with their respective capabilities.

As countries review their climate policy the focus must shift from just considering annual emissions to the allocation of the remaining global carbon budget of cumulative emissions, national carbon budgets as the basis for developing and assessing strategies and a time-table for joint research and development of new technologies, as well as mechanisms for their transfer, to meet the scale and speed of the response. The shared vision must also recognize that only with new technologies at competitive prices can climate change be curtailed without sacrificing growth and well being.

# A Note on Carbon Space as Development Space

Prabir Purkayastha
Tirthakankar Mandal

The climate change negotiations have currently reached an impasse on two crucial questions. One is how the remaining carbon space would be "shared" between countries and the second is who bears the costs due to the already high stock of greenhouse gases that have accumulated in the atmosphere. If rich countries cut back on their current high carbon path slowly, the burden of cutting global emissions would fall disproportionately on the global south. This is the strategy that the developed countries seem to have adopted in the run down to Copenhagen and after.

The unfairness of this climate change issue is while the rich countries have caused the problem due to their high stock of CO2, the impact of climate change is going to be felt primarily in the global south. The developing countries would have to pay in two ways for the carbon space captured by the rich countries – they will have to adopt a far more expensive low-carbon trajectory for their development, as well as pay for the impact of higher temperatures through costly adaptation measures. The low lying countries have of course the additional danger of losing large parts of their land due to rising sea levels. That is why early and deep cuts by the rich countries are so critical to the developing world.

The developed countries are arguing that countries such as India should work out a low carbon low energy path. Without any commitments by the rich countries to transfer either knowledge or resources for such a low carbon low energy path, the developing countries might have to cut down on future development and forego cheap energy options in order to lower emissions. Without any commitments on knowledge – read Intellectual Property – the developing countries would in all probability have also to pay high monopoly prices for low-carbon technologies. A lock-in to a low carbon path without any consideration of costs and technology appears to be foolhardy as a negotiating strategy for the developing countries. In effect, it would lock-in their underdevelopment permanently and would violate the fundamental premise of Kyoto that development is the priority for developing countries.

Table 1 provides some figures on the disparity between per capita consumption of energy and per capita emission between the rich and the developing countries.

**Table 1: Energy, Emissions and GDP Per Capita at Purchasing Power Parity (PPP) for Selected Countries (2007)**

| Countries | Per Capita GDP at PPP($) | Per Capita Consumption (kgoe) | Per Capita Consumption (KWhr) | Per Capita Emissions (CO2 Tons) |
|---|---|---|---|---|
| India | 2,600 | 528 | 542 | 1.3 |
| China | 5,085 | 1,484 | 2,332 | 4.3 |
| Germany | 33,183 | 4,026 | 7,184 | 9.5 |
| US | 43,031 | 7,766 | 13,651 | 20 |

(Source: WDI, 2010, http://databank.worldbank.org)

*Note:* China's per capita emissions are currently closer to 6 tons/capita, while India's are around 1.5 tons/capita. The global average today is around 4.4 tons/capita.

Though China is currently the highest emitter, coming ahead by a whisker from the US, and India is the 4th highest emitter, by per capita emissions, they are well below the rich countries. India is not even in the same league as China or other emerging economies – its per capita income and energy use would put it in the bottom 40% of the world. In per capita terms, India consumes energy less than 1/15th that of the US and also emits 1/15th the US emissions. It is a poor country, not only by its income levels, but by any other indicator including energy.

There is an argument advanced that while India's per capita consumption may be low, India's burgeoning middle class with its increasing consumption levels is still a problem for absolute global emissions. In this argument India asking for a higher carbon space is nothing but the Indian rich hiding behind its poor. The problem with this argument is that India's middle class is neither as big nor is its consumption as high as is being argued. A CSE study[1] has shown that even the richest 2% of Indians have consumption levels that are equal to or below that of the poorest 10% of Americans. The Princeton study[2] also comes to more or less the same conclusions – the number of Indians in the 1 billion high emitters who have to cap their emissions is only a minuscule 1 million if we consider their base case. Even in their modified case, which increases the number of high emitters, India still has only 2 million high emitters. This is consistent with calculations regarding India's middle class and its energy consumption and emissions.

The purpose here is not to argue that there are no disparities in India – obviously there are sharp differences in consumption and incomes in India. Even taking into account these disparities, the fact remains that India is still in many ways a poor country with massive development deficits that need sustained attention.

Before the Copenhagen Summit, the two major developing countries – China and India – announced unilateral targets for carbon intensity of the GDP. Though China's target – 40-45% reduction in the carbon intensity of GDP by 2020 (taking 2005 as the base) is much larger than India's target of 20-25% for the same period, it must be factored against a much higher per capita figure for China in terms of carbon emissions. Currently, China emits about 6 tons per capita of Carbon dioxide as against 1.5 tons in India and 4.4 tons as the global average. Of course, if we take into account the current emissions of the rich countries, China can still claim to be very much below countries such as the US which has more than 3 times per capita emissions than that of China and about 15 times that of India. The historical emissions, or the stock of CO2 emitted and still in the atmosphere, of the rich countries are of course far higher.

The key question is what are the implications of following a lower carbon intensity path and what are its costs? Do we have a coherent strategy that integrates such a path of development with climate concerns?

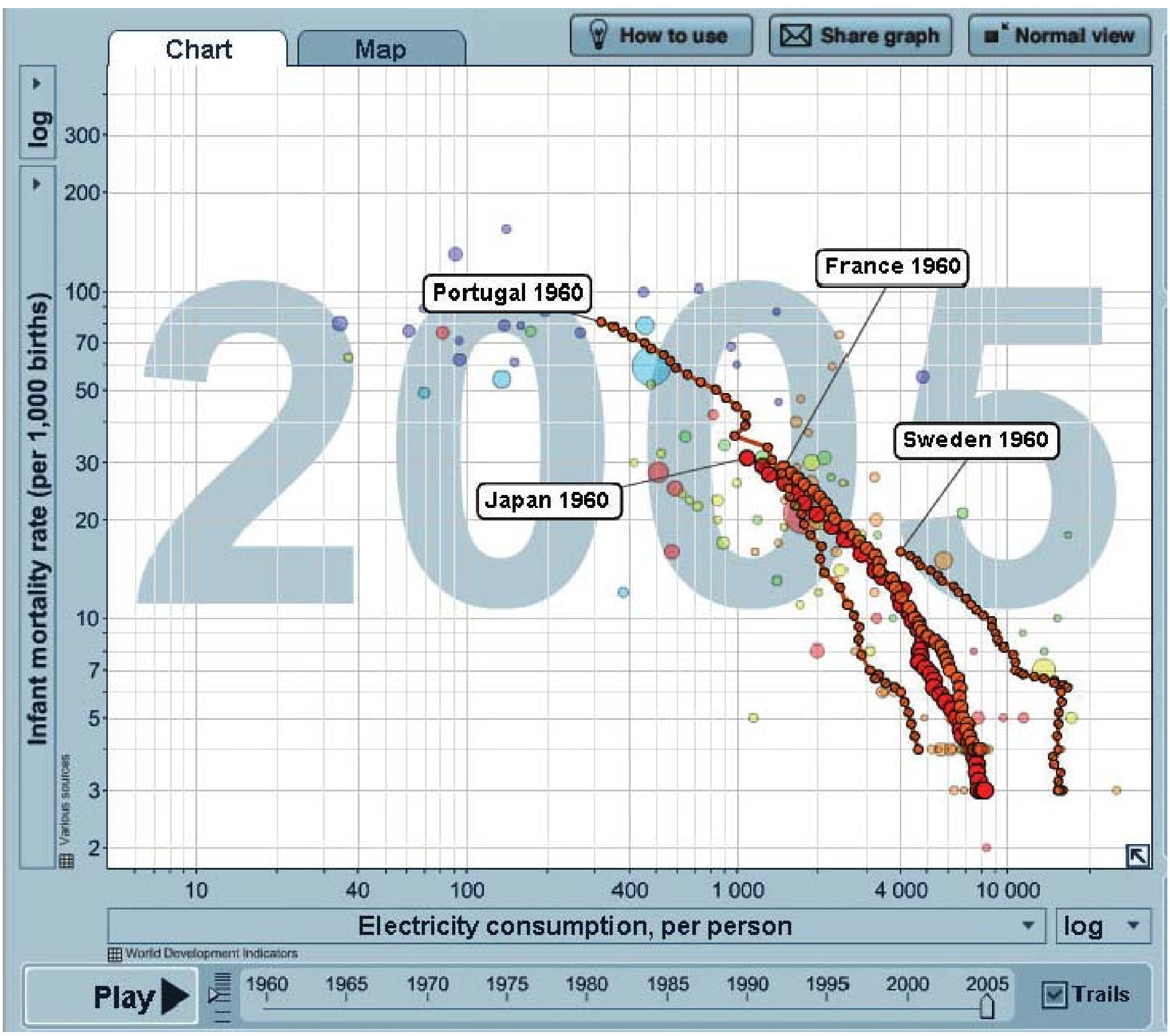
It is true that GDP growth and energy growth need not be tightly coupled – it is possible to have GDP growth without simultaneously increasing energy consumption. This is what the rich countries are now doing; once a country reaches a certain level of development, it is possible to change from a manufacturing to a service economy. The question that India confronts is whether it is possible to reduce energy intensity of the economy before reaching a minimum level of development? This, no country has yet done.

It is possible to argue that GDP growth and quality of life are two different issues. A consumption oriented society would have high GDP, even if the consumption is inherently wasteful. For example, changing the mode of transport from public to private would see a large jump in GDP – more cars and higher consumption per passenger-kilometre. However, it will still provide the same function of taking people from one place to another. For this reason, it is necessary to consider other parameters to capture development and not just the GDP, e.g. life expectancy, infant mortality, etc. One could use the Human Development Index (HDI) in this regard[3] , but since HDI has an inherently exponential character, it levels off after a certain point. Instead, we take indicators a such as infant mortality or life expectancy, the trajectory for which would have some physical meaning and would not level off like an artificially constructed index such as the HDI.

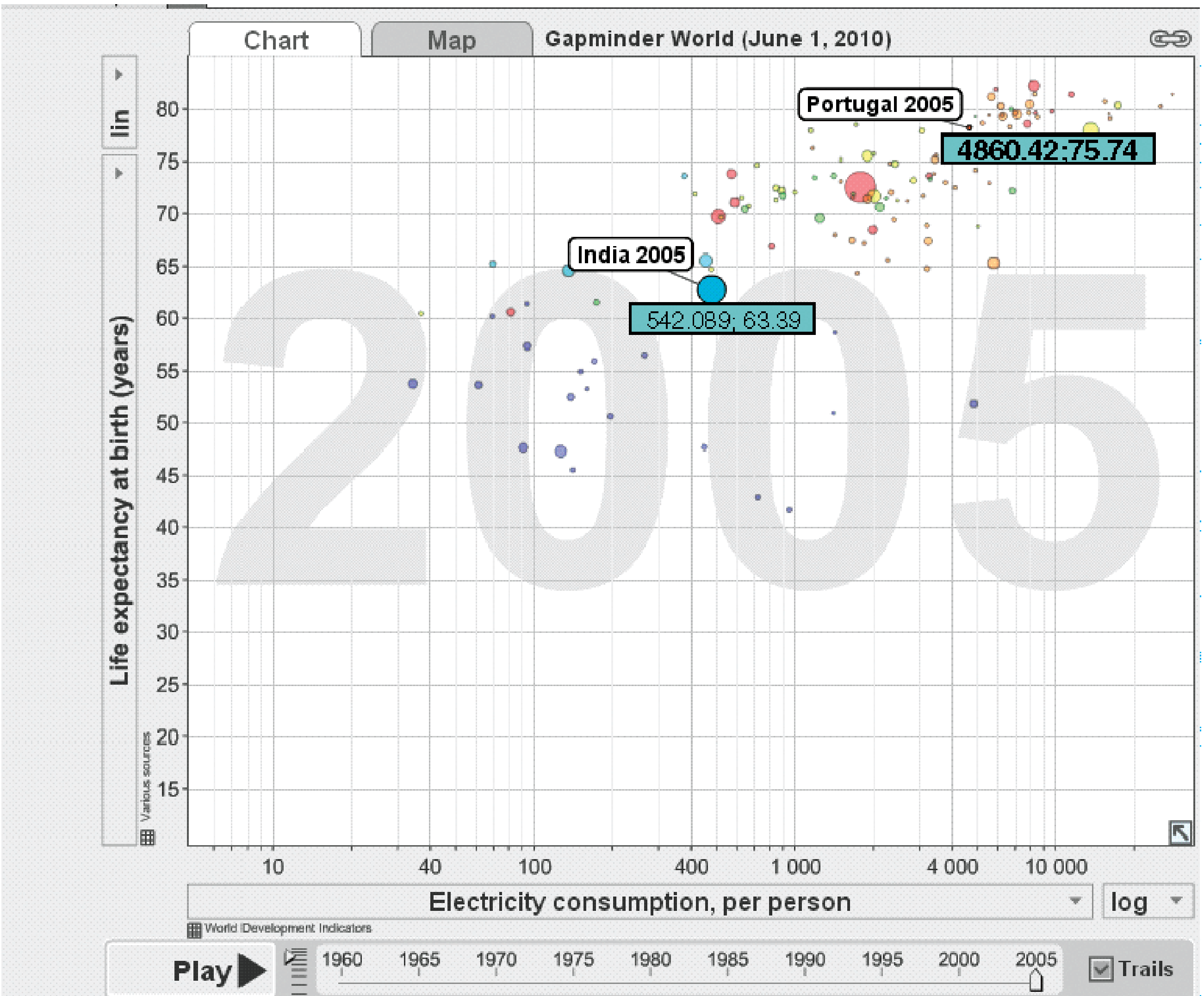
Due to better availability of data with respect to production/consumption of electrical energy, we have used this as a proxy for energy consumption. If we take the correlation between energy as measured in electrical energy consumed per capita and other Human Development Indicators, there is a strong correlation up to a certain point, after which it starts to weaken. This would indicate that a minimum of energy consumption per capita is required for achieving a certain level of development. One can argue on what this point is but by any reckoning, it lies well above India's current low level of energy consumption. If we have to provide for development and even a minimum level of energy consumption for the majority of the Indian people, India's per capita energy consumption would have to increase significantly.

The question is what is a reasonable level of energy consumption? For this purpose, we have taken the current consumption levels of different countries and plotted it against the human development indicators of infant mortality and life expectancy. If we now take two different curves – one that runs through the countries with lower energy consumption and another that runs through countries with higher energy consumption, for comparable levels of HDI indicators (infant mortality) -, we get a scenario that defines what can be physically done with current levels of technology. The chart below shows a set of countries which have relatively high human development indicators. It shows the envelope of what can be done with today's technology and organisation of society. Therefore, it is possible to achieve a certain level of human development, with relatively lower levels of per capita consumption as those of Portugal, which has lower energy consumption for the same level of human development as compared to other developed countries.

The Energy-Infant Mortality Band for Developed Countries




Source :http://graphs.gapminder.org




| Table 2: India's Energy Consumption at 8% growth rate | | | | |
|---|---|---|---|---|
| | Electricity(Kwhr) | Population(Billionn) | Total(BKwhr) | % Growth |
| 2007 | 542 | 1.12 | 607 | 8.00% |
| 2020 | 1208 | 1.37 | 1,651 | |
| 2035 | 3427 | 1.53 | 5,237 | |
| 2038 | 4256 | 1.55 | 6,597 | |
| 2040 | 4907 | 1.57 | 7,694 | |

Source: UN World Population Prospects for population, growth computed

| Table 3: India's Energy Consumption Pathway at 9.1% growth rate | | | | |
|---|---|---|---|---|
| | Electricity(Kwhr) | Population(Billionn) | Total(BKwhr) | % Growth |
| 2007 | 542 | 1.12 | 607 | 9.1 |
| 2020 | 1,378 | 1.37 | 1,883 | |
| 2035 | 3,910 | 1.53 | 5,974 | |
| 2038 | 4,855 | 1.55 | 7,526 | |

Source: UN World Population Prospects for population, growth computed

If we consider Portugal's per capita energy consumption of 4,860 as a minimum target, India will reach this figure by 2039-40 assuming a growth rate of 8% for electricity consumption. For reaching a figure of close to Portugal's current figure by 2038, it will need a growth rate of at least 9.1 %. If we assume that India's generation to consumption efficiency will improve in this period – India has a large transmission and distribution loss today which is really disguised consumption -- it is possible to achieve levels similar to Portugal in the years between 2035 and 2038.

The argument that India should cut its emissions, either translates to India restricting its per capita energy consumption or suggesting that India should continue to expand energy consumption but restrict its emissions – make a fundamental change in the ratio of emissions to energy, i.e. take a low carbon path. The next section deals with the costs of taking such a low carbon path.

## Low Carbon Path

In the medium or long term, a low carbon path can be achieved through either the nuclear or solar route, or a combination of the two. While short term gains can be made by shifting a part of future growth to gas, this can at best be for a limited amount and a limited period. For India, wind and biomass are not major sources. India has limited wind resources. Biomass has competing uses – both as fuel and as cattle feed. It has also the problem of being seasonal and most biomass based plants have encountered problems in procuring biomass.

We have not considered carbon sequestration as an alternative. This could allow continued coal use, but at a higher cost. The cost of carbon sequestration is not clear at the moment – either as capital per KW or as variable cost per unit of electricity. Once these figures are known, we can consider them as well. However, we need to be cautious regarding the stability of the geological reservoir in which we pump back the CO2. There is also the possibility that a few companies controlling the technology may impose monopoly rent on the developing countries, making the cost of carbon sequestration prohibitive.

For India, nuclear power could become a major component in the future – 40,000 MW by 2020 was propagated during the India US nuclear deal. The other route is solar -- 20,000 MW solar thermal plants by 2022 as has been proposed in the National Solar Mission is a start in this direction.

The accelerated nuclear route of 40,000 MW envisages large-scale import of nuclear reactors from the US, France and Russia. India has offered[4] to buy 10,000 MW from the US suppliers. Going by the filings before the regulatory commissions in the US, the Moody's Investor Services agency now estimates the cost of nuclear power to be around $7,500 per KW ($ 7.5 million per MW) or about Rs. 35 crore per MW. This is about 6 times that of coal–fired plants. The Areva reactors being set up in the Olkiluoto 1,600 MW plant in Finland, has also had huge cost and time over runs and is likely to be around $5-6 million per MW or about Rs. 23-27 crore per MW. While the Indian technology developed by DAE would be a lot cheaper, the fact remains that a rapid increase of nuclear power can happen only with large-scale imports. This would then involve high capital costs for such imported reactors.

The solar thermal route is another possible low-carbon route. Using a solar route, the capital cost would be around Rs. 20 crore per MW ($ 4.5 million per MW) or about 5 times that of coal fired plants. But that is not all. Since the Plant Load Factor (PLF) is about 25% for solar plants as against 80% PLF for coal-fired ones, we will have to install about 3 times as many solar plants – the capital cost for producing the same amount of electricity from solar plants is about 15 times that using the coal route or a high carbon route! So choosing a low carbon path has huge costs.

Such high capital costs imply that for producing the same amount of electricity, developing countries such as India will have to find large amounts of additional capital. For the kind of electricity generation that India needs over the next 20 years, this would imply astronomical sums of capital and would deny other sectors of the economy access to capital.

This is not the only problem of solar or nuclear power. If capital has a cost – cost of borrowings being obviously one of them -- then this cost of capital would reflect also on the cost of electricity. Even assuming that operating costs for nuclear or solar plants are low, it would still involve the cost of electricity to be 4 times higher than electricity from coal-fired plants for nuclear energy and 9 times that of coal-generated electricity for solar energy..

| Table 4: Comparative Costs for Coal, Nuclear and Solar Plants | | | |
|---|---|---|---|
| **Item** | **Cost/MW($ Million)** | **PLF** | **Cost/KWhr(Cents)** |
| Coal Fired Plant | 1.2 | 80% | 6.4 |
| Nuclear Plant (Imported) | 7.5 | 80% | 25.3 |
| Solar | 4.5 | 25% | 54.2 |

*Note:*

1.The imported reactors refer to Westinghouse, GE or Areva reactors. The current generation of Indian reactors are cheaper.

2. The costs of solar plants are from the project costs of plants being developed in India currently.

Finally, let us look at the cost of avoiding carbon per unit of electricity against its price in the CDM market today. The amount of avoided carbon per unit of electricity – if we switched from a coal-fired plant to a low carbon route is about 0.4 kg. The CDM market prices this at less than 1 cent, while the difference in costs from the two is around 48 cents. This brings out the problem of dealing with this issue, especially in a market based approach.

When the developing countries talk about financial and technology transfers for the carbon debt that the rich countries owe the rest, they are not talking about some notional costs, but the additional burden that they will have to bear because of a lack of carbon space today. On the one hand, they have to adopt high cost technologies for reducing emissions, on the other they also have to pay monopoly prices to global MNC's to buy such technologies. The demand of developing countries that the rich countries make financial and technology transfers to developing countries is not a request for charity but a demand for justified financial transfers for this additional burden of adopting a low-carbon path.

| Item | Value of Carbon (CDM $10/Tonne) (cents) | Cost per Unit using High Carbon Path (cents) | Cost per Unit using Solar Low Carbon Path (cents) | Difference (cents) |
|---|---|---|---|---|
| 1 unit of avoided carbon per Kwh | 0.39 | 6.4 | 54.2 | 47.8 |

1 Richest Indians Emit Less than Poorest Americans, CSE Study, http://old.cseindia.org/equitywatch/pdf/richest_poorest_emissions.pdf

2 Shoibal Chakravarty, Ananth Chikkatur, Heleen de Coninck, Stephen Pacala, Robert Socolow and Massimo Tavoni, "Sharing Global CO2 Emissions Among 1 Billion High Emitters", Proceedings of the National Academy of Sciences, July 7, 2009.

3 Narasimha Rao, Girish Sant, Sudhir Chella Rajan, Indian Institute of Technology Madras, "An overview of Indian Energy Trends: Low Carbon Growth and Development Challenges", Prayas.

4 William Burns, Under Secretary of State for Political Affairs on September 18, 2008 before the Senate Foreign Relations Committee testified, "The Indian government has provided the United States with a strong Letter of Intent, stating its intention to purchase reactors with at least 10,000 Mega Watts (MWe) worth of new power generation capacity from U.S. firms. India has committed to devote at least two sites to U.S. firms".

# Equity, Energy Access and Global Carbon Space

**Surya Sethi**

Let me begin by thanking the organisers for giving me the opportunity to address this conference. I would like to share my views on the question of equity, and access to energy and development space in a carbon constrained world within the context of the background paper of the conference.

My long held view has been that the only equitable solution to burden sharing, in the context of climate change, is a defensible allocation of the global environmental commons as entitlements with penalties or reparation attached to exceeding such cumulative entitlements in any year, unless the excess use is funded through purchase of entitlements in an open market. India, home to 17 % of humanity, over a third of the world's poor and about half the world's malnourished, will pay the highest economic and human price for climate change – indeed evidence is mounting that it already is. Given India's recognised intellectual capital both at home and overseas, it is India's responsibility to support development of an equitable solution and sell it to the rest of the world. While questioning Lord Stern's formulation of equity, I had, in late 2009, written to the Prime Minister of India that the best way for India to be part of the climate solution was to craft an equitable burden sharing model and present it to the world on behalf of the bottom 50% of the world that is responsible for only about 11% of the problem but will be the most and the worst affected. India is unique among the G-8 plus five, the G-20 and even the BASIC group as the only country that has significant development deficits across a wide variety of socio economic indicators. I emphasize significant because India is not even at the top of this bottom 50% by some indicators. Even within the BASIC group, the per capita GDP, energy usage and emissions of India are 35% or lower when compared to the other three. India faces the same vulnerabilities of poverty, access, and equity as the bottom 50% of the world but on a larger and unmatched scale.

Given this backdrop I am sure you will all join me in appreciating the work of the climate team at the Tata Institute of Social Sciences. The background paper raises many questions that beg defensible answers not assumptions: for example is population alone a sufficient criteria for allocating global carbon space, can one justify a base year for counting cumulative use of carbon space without also freezing national populations in the same year, what is more critical – emissions from within national boundaries or consumption, how does one adjust for changing patterns of consumption and production, how does one adjust for life-style differences, intra national inequities and national capacities, is it not better to have an objective function that ensures a minimum threshold level of income and consequent well being for every human being etc; etc. We must find answers to such questions not only because they will be raised but also because the answers will improve the allocation framework as proposed in the background paper, and its acceptability.

The background paper and the model presented in it rightly emphasize historical responsibility which I have consistently maintained is the foundation of the Common But Differentiated Responsibilities principle. An equitable solution to mitigation and adaptation, within the provisions of the United Nations Framework Convention on Climate Change (UNFCCC), is not possible without accounting for historical responsibility. More importantly, the paper emphasizes that equitable burden sharing in the case of mitigation requires that the developed world vacates the global carbon space that it has occupied well beyond its fair share. Some proposals have put forward the concept of rent for occupation of the global commons. Unfortunately, with regard to future emissions, the rent concept is tantamount to saying that the solution to the current inequitous distribution of living space in the city of Mumbai is for the elite, who have a disproportionate hold on the city's residential and related infrastructure, to pay a rent for distribution to the pavement and slum dwellers who are quite used to living as they are without any or limited civic amenities. Such prescriptions would do little for inclusive growth and will only perpetuate our difficulties in effectively addressing issues of poverty and access to energy. A penalty/reparation under the polluter pays principle is one thing, a rent that legitimizes occupation of global commons or a right to pollute is quite another.

One issue in the model is that even though the objective function of the exercise seeks to equitably allocate the global carbon space the results under the four scenarios do not really provide an equitable solution. The US continues to occupy more than twice its fair share of carbon space and the EU continues to occupy 60-70% more than its fair share. China and some emerging economies are at or within 5-10% of their fair share but India and the Rest of the World grouping are 30% or more away from their respective fair shares. A possible reason for this anomaly could be that the model does not allow the largest historical polluters to have negative entitlements. Again, based on work done independently, I and others have long argued and demonstrated that the major historical emitters would need to have negative entitlements for true equity to prevail by say 2050. For large historic emitters, this would require significant actions within their borders and action beyond their borders, with finance and technology .

Equity has both an international dimension that seeks equitable developmental space and a domestic dimension that then must ensure that the development space so obtained actually translates into improvement in the lives of the poor. If this does not happen, it would be correct for the developed world to say that the developing world is hiding behind its poor. It is a matter of concern that during the years that India has delivered high GDP growth, its HDI has actually slipped 8 ranks to 134 among 180 nations.

Let me emphatically repeat what I have said earlier -- the right to development is not a right to pollute. During the 4 years leading to Bali, India made some memorable presentations at the UNFCCC and the Intergovernmental Panel on Climate Change. In 2006, India showed the incremental amounts of energy needed and the consequent incremental emissions for meeting each of its development goals such as gender equality, universal education, public heath, reduction in infant mortality rate, maternal mortality rate and poverty, providing livelihoods, increasing forest cover, improving connectivity, cleaning our rivers etc. Most of India's development goals mirror the MDGs.

In 2005 and 2007, India demonstrated what would happen to its emissions if its lifestyles approached Western life styles in consumption of food, space conditioning, transport, waste, recycling or in consumption of steel, aluminium and cement per unit of infrastructure. India showed that most of her energy intensive sectors were operating at internationally competitive efficiency levels. And that most abatement options came at a price.

In its presentations India showed that it had more than halved its energy intensity in the previous 20-25 years. Just before climate change conference in Bali in 2007 the World Bank released a study, done under my guidance, that showed that India was unique in the developing world to have dissociated its economic growth from the growth in its energy consumption and India would continue down that path with a further improvement in energy intensity to the extent of 20-25% by 2031-32 and an emissions growth of around 3% per annum. The Indian presentations demonstrated that India was not following the "fuellish" growth trajectory of the developed world. Several new committees have been appointed and several independent groups are revisiting these very same issues and I am happy to say that they are reaching pretty much the same conclusions.

But despite all of the foregoing, I have and continue to maintain that going forward India would need more energy and will continue to increase its emissions to somewhere between 3.5 to 4.0 gigatons of $CO_2$ equivalent by 2031-32 even under its sustainable growth strategy. If India delivers this, eradicates poverty and meets the MDGs then India would clearly be a part of the climate solution.

1 The critique here refers to the original version of the background paper of the conference. The issues raised here are further addressed in the final version of the paper in this volume. (Eds.)

Let me share five inconvenient facts about equity at the international level to illustrate this point:

1. Based on BP statistics, the incremental primary energy consumption in OECD countries between 2002 and 2007, in absolute terms, was about 2.1 times that in India over the same period. The population of OECD countries is slightly less than that of India. So despite OECD's advanced technological and developmental level and already high income and consumption levels, OECD countries continue to disproportionately increase their consumption of global commercial energy supplies. Clearly population and growth numbers alone are misleading. A one percent growth in OECD raises consumption much more than a 1% growth in India.

2. Between 1990 and 2007 the annual emissions of OECD grew by over 2.2 gigatons despite the one time beneficial impacts of Russian hot air, German unification and the switch to gas from coal in the UK. India's absolute annual emissions during the same period grew by less than half that amount despite the increase in the share of coal.

3. Despite absence of barriers to technology transfer and financial constraints, the energy intensities within OECD vary by a factor of almost 2.5 and such a variation cannot be justified only by climatic and geographical niceties.

4. The chasm between sustainability and equity has been exposed. The world has reached the limits of growth without bridging the huge gap between the haves and the majority have-nots. And although eliminating poverty and delivering equitable growth to a certain degree, is still possible within the available carbon budget, the developed world has, by its reluctance to reduce its consumption and emissions, has unwittingly proven beyond doubt how undesirable or impossible such a pathway really is.

5. A pledge by the developed countries to reduce their emissions by 80% by 2050 actually seeks a right to a disproportionate share of global energy supplies and the global environmental commons till 2050 and beyond. Fortunately, thanks to China and the other BASIC countries, the Copenhagen accord was expunged of any language that conferred this free ride to the developed world.

Clearly the developing world will not have the same free run as the developed world did in an era without carbon constraints. And clearly the bottom 50% of the world, where a majority of Indians reside, will never reach the levels of energy consumption and the emissions of early-starters within the developing world such as China, South Korea and others. I do not believe that we can deliver acceptable levels of development for every citizen of the world while the OECD and the rich in the developing world continue to grow their consumption levels at the expense of our planet's limited energy and natural resources.

A word on technology would be appropriate before moving to the domestic issues of equity and access. It is quite fashionable for some to argue that technology will yield new development pathways that will continue to support higher consumption at all income levels in the "ever-more-prosperous" brave new world with a population of 9 billion. I grant that technology development is full of surprises and a disruptive technology can indeed change the equity, access and development paradigm. However, there exists an inconvenient disjunction between theory and practice that some economists tend to cover with make-believe bridges. There is no projection in the world that shows a lowering of global dependence on fossil fuels in absolute terms till 2030. Most scenarios show a continuing rise in energy consumption at the rate of at least 1.4 % per annum with nuclear and renewable energy, including all hydro, growing a little more rapidly at 2% and 2.6% per annum respectively till 2030. So while nuclear and renewable energy shares in the mix would rise from 5.5% to 6.3% and 10.1% to 13.2% respectively, the inconvenient truth is that we would still consume 33% more fossil fuels in 2030 compared to 2007, despite technology.

No doubt technology will help deliver more energy services and more GDP growth per unit of incremental energy consumption. However, no one is forecasting numbers that show that new technologies will allow us to reduce or maintain fossil fuel consumption compared to the 2007 level. To my mind one fail-safe way that addresses development, equity, access and climate change is to redistribute current consumption more equitably. History is replete with revolutions that had this objective as their genesis.

And this makes the issue of domestic equity and access all the more complex and critical.

The 2006 Integrated Energy Policy (IEP) report showed that even if India were to deliver commercial energy consumption levels that were 4-5 times the 2003-04 level by 2031-32 at an annual growth rate of 5.2% to 6.1%, the per capita commercial energy consumption of Indians in 2031-32 would equal only 65% of global average in 2005 and be below the Chinese consumption level in 2005. The projections in the IEP, like most projections, assumed falling elasticity of energy demand for India and showed that even under an optimistic 2% annualized growth in global energy supplies India would need to raise its share 2-3 times by 2031-32 even to meet its conservative energy growth targets. However, at the actual rate of growth in her share in recent years, it will take India 40 years to double its share of global commercial energy supplies.

Over 550 million Indians live without access to electricity and over 700 million Indians depend upon bio-mass as their primary or only fuel for cooking. Almost 80% of Indians live below the $ 2 per day threshold. At any poverty line between $ 1.25 and $ 2.50 a day, the number of poor in India is 17 to 54% higher than Sub-Saharan Africa. India is the most impoverished nation or region of the world. These numbers are consistent with the findings by recent reports in India on the country's poverty. Energy, including the meagre allocation of kerosene under the public distribution system of under a litre a month (most of which gets diverted to other uses), is simply priced outside the reach of these unfortunate Indians. And yet the learned elite in India talk of energy markets – especially when it suits them to do so.

A recent study of the World Bank establishes 10 nominal dollars a day as the income that one must have to be considered a part of the middle class in the developing world. The poverty line in the US is 29 nominal dollars a day. Only 5% of Indians have an income of more than 10 nominal dollars a day. And even if one grants that the World Bank may have missed the parallel economy that exists in India, the number of Indians earning 10 nominal dollars or more a day cannot be more than 80 to 100 million. The Greenhouse Development Rights establishes 7500 dollars as the level of annual income in PPP terms as the threshold that every human being should be entitled to and India indeed has a long way to go to ensure that at least 80-85% of its households actually earn that on a per capita basis. We cannot deliver this without giving every Indian adequate access to energy

In conclusion let me simply say that, especially in a carbon-constrained world, the development paradigm that India is following has to be thoroughly reworked if equity and access are considered critical.

# Conference on ``Global Carbon Budgets and Equity in Climate Change''

## Summary Report

The conference on ``Global Carbon Budgets and Equity in Climate Change'' was held at the Tata Institute of Social Sciences, Mumbai, on 28-29 June, 2010. The conference was organised jointly by the Centre for Science, Technology and Society, School of Habitat Studies, Tata Institute of Social Sciences, and the Ministry of Environment and Forests, Government of India. The Ministry provided financial support for the meeting with additional top-up funding being provided by the World Wildlife Fund – India. The conference was inaugurated by the Honourable Minister of State (Independent Charge), Environment and Forests, Mr. Jairam Ramesh, who was also present during a major part of the proceedings of the first day of the meeting.

### Key Highlights from the Conference:

- The conference expressed broad support for the carbon budget approach as a means of operationalising the concept of ``equitable access to global atmospheric space'', based on the principle of per capita equity of accumulated emissions (or stock) in the atmosphere as the basis for deciding on the fair share of the global carbon space for all nations (within the framework of the UNFCCC and the Kyoto Protocol).
- Immediate and steep reductions in emissions by the developed nations is the key to freeing physical carbon space for the development needs of the rest of the world.
- The acceptance of global mitigation targets without such immediate and steep reductions will lead to considerable loss of carbon space for the developing nations.
- The over-occupation of carbon space by the developed nations (within a global carbon budget) will lead to most developing nations not physically realising their full entitlement by 2050. The unrealized entitlement needs to be part of the basis for computing financial and technological transfers to the developing world by the developed nations.
- Low-carbon pathways of development for the developing nations will be expensive and the basis of computing such costs needs to take into account the real cost of avoided carbon emissions when switching from fossil-fuel based technologies to renewable resources as the source of energy. The valuation of the carbon space entitlements that developing countries are unable to physically access should be related to such costs.
- The over-occupation of carbon space by the developed nations gives rise to the question of ensuring the fair and equitable distribution of physical carbon space among developing nations.
- The carbon budget approach needs to be carried forward as the appropriate equity-based perspective in the global climate negotiations. It has important implications for several aspects of the negotiations including (a) the shared vision for long-term co-operative action, (b) burden sharing in mitigation between developed and developing nations, (c ) monitoring, reporting and verification issues for developed and developing nations, including specifying reductions for the developed countries in gigatonnes (rather than percentage reductions with respect to a base year) and (d) financial and technology transfer related issues.
- The conference expressed interest in taking the carbon budget approach forward and hoped that apart from discussing this approach among the BASIC countries and G77+China, India would also carry forward this approach by suitable means using its own influence and presence in the global climate negotiations.
- The conference identified several technical issues in the carbon budget approach that would need to be studied further.

## Background:

The original conference proposal had noted that the perspective of carbon budgets was gaining considerable traction in analytical discussions in the academic and policy literature on burden-sharing in climate mitigation. While it had not yet become explicit as a mainstream option in the UNFCCC negotiations, the perspective was beginning to inform policy formulation at the national level in various developed countries.

At the negotiations, India had also officially signaled its interest in this perspective in its submission to AWG-LCA prior to the Bonn round of June 2010 by referring to the ``equitable sharing of global atmospheric space based on per capita accumulative emissions''. It had noted that such a paradigm needs to precede the goal of stabilizing global temperature rise to 2 deg C above pre-industrial levels. It had also noted that ``Global atmospheric resource is the common property of all mankind and each human being has equal entitlement to use of this resource on the basis of per capita accumulative convergence of emissions.'' Further, the principle of ``equitable access to global atmospheric space'' had also been part of the G77+China position on shared vision and long-term goals in the AWG-LCA discussions and the phrase itself had been part of the AWG-LCA text emerging from the work of the AWG-LCA at COP 15 at Copenhagen.

Simultaneously academic work in India had also been developing on the theme of carbon budgets. An earlier conference in 2009 at Mumbai, convened jointly by the Tata Institute of Social Sciences and the Delhi Science Forum (DSF) had been the occasion to initiate work on carbon budgets in the context of equity in climate change by the TISS-DSF collaboration. This work had been carried forward to a more detailed and comprehensive approach outlined in a paper prepared in April 2010. The paper was presented at a conference on the carbon budget approach convened by the Chinese Academy of Social Sciences at Beijing in the same month. This conference was also the occasion for the exposition of the carbon budget approach originating from other countries such as Germany, China and Japan. The common theme in these approaches was the recognition of the principle that each human being has equal entitlement to the use of global atmospheric space, though there remained many differences on operationalising this principle. A number of other writings and academic work from India had also enlarged on the theme of equal per capita entitlement to global atmospheric space.

In this background, TISS made a formal proposal to the Ministry of Environment and Forests, Government of India, to urgently convene a conference to have a focused discussion on the issue of carbon budgets and equity using the April 2010 TISS-DSF paper as the background, with both wide-national participation and some international participants.

## Proceedings:

The agenda of the meeting, with the detailed list of talks and presentations made is appended to this report. The written version of these talks, copies of the presentations made at the meeting, as well as supplementary material provided by several distinguished participants will be made available on the website of the TISS at http://www.tiss.edu and the website of the Ministry of Environment and Forests at http:// www.moef.nic.in (and other websites willing to mirror this material). We will also not cover in detail the issues highlighted in the three additional contributions, apart from the main paper, in this publication.

## (a) The Carbon Budget Approach:

### i) Distinguishing between entitlement to carbon space and the availability of physical carbon space:

In the discussions that followed the presentations based on the background paper, and indeed as a running theme in other sessions that followed, the need to distinguish between physical carbon space and its availability for developing countries and the actual entitlement of developing countries based on the equal per capita access to global carbon space was the most prominent issue raised. To speak to the physical availability alone without reference to the entitlement would, it was generally felt, be tantamount to the acceptance of the status quo, abandoning thereby the question of historical responsibility as well as sanctioning the continued over-occupation of global carbon space by the developed nations. The consequence of such considerations would of course be that developed nations would have negative entitlements and these would undoubtedly form the basis for computing the financial and technological transfers that the developing world would need. Such financial transfers could undoubtedly also take the form of rents that the developed nations would have to pay for their over-occupation of carbon space. Though the extent to which such rents could be considered as a solution to future over-occupation was unclear since it involved the loss of physical carbon space. In reference to this issue it may be noted that the background paper had kept track of both the physical carbon space as well as the over-occupation by the developed countries. The latter is equivalent to keeping track of negative entitlements. Hence the background paper had not really lost the distinction. However since the language of entitlements was more clearly acceptable and most participants felt that the negative entitlement formulation made for a clearer statement, the authors accepted this shift of language.

**ii) Actual emissions trajectories for particular developing regions/nations only need to satisfy the constraint of not exceeding the physical carbon budget (suitably determined) for that region/nations. Within that constraint they are flexible, including with regard to peaking years.**

A second major issue of discussion was the extent to which the emissions trajectories produced by the TISS-DSF model could be taken as representative of the actual emissions trajectories that various regions/nations would need to follow. While the background paper had clarified that the actual emissions trajectory need only take into account the carbon budget and that a number of emissions trajectories were possible, it was also evident that the basis of the discussion lay partly in a lack of emphasis on this issue in the background paper. In the course of the discussion it became clear that the correct reading of the model results were to take the carbon budget for each region/nation as the basis and that there would be several emissions trajectories that would be compatible with this budget. However especially for current large emitters who would be significantly close to their physical entitlement by 2050, the flexibility in the choice of emissions trajectories would be relatively limited. A possible route for improvement of the model would also be to try and generate a family of emissions trajectories that would all cover the same carbon budget but with different peaking years etc.

**iii) Since the availability of physical carbon space will be limited, there is an important issue of the fair and equitable partitioning of the remaining physical carbon space among developing nations.**

Clearly a significant result of the carbon budget perspective, that runs counter to a cherished trend in climate policy from developing nations, is that despite the deepest possible reductions by the developed nations there would nevertheless remain the key issue of a fair and equitable partitioning of the physical carbon space among the developing nations. It was clear from the discussion that the conclusion that large emitters among developing countries, especially the emerging economies with significant emission rates, would have to take significant mitigation action much earlier than other developing nations, occasioned much discomfort. However much of this discomfort appeared to stem from the need for an united stance by the developing countries at climate negotiations rather than a rejection of the computational results per se.

**iv) The change of basis year from 1850 to 1970 does not change the amount of physical carbon space that would be made available by the emissions reduction of the developed nations. The change of basis year results however in a somewhat different allocation of the remaining physical carbon space amongst developing countries.**

A similar trend in the discussion was also occasioned by the discussion of the possible shift of the base year for computing historical responsibility from 1850 to 1970. Much of the discussion centered around the issue of whether this shift of base year downgrades the entitlement of the large emitters among the emerging economies and drives a wedge between their interests and the rest of the developing world. In response to this critique it was pointed out that the availability of physical carbon space for developing nations is determined by the extent of emissions reduction by the developed nations, beginning from specified year in the current era. Issues such as the shift of base year for historical responsibility however determine only the nature of the partitioning of the remaining physical carbon space among developing nations. The evolving consensus on the need for the separation of entitlement to carbon space from the issue of the physical availability of carbon space did however assuage this concern to some extent.

These considerations however do not change the issue of the actual entitlement of developing nations to a fair share of carbon space. The shift of base year for entitlements however lowers the negative entitlement of the developed nations for the period 2010-2050 from approximately -127 GtC to -100 GtC and lowers the entitlement of some large developing countries, particularly China.

**v) Shifting the basis for entitlements for carbon space from a moving population basis to constant population based on a single base year does not benefit all developing countries.**

Some discussion also centered on the issue of whether to take constant population or varying population in determining the fair share or entitlement of regions/ nations. While the constant population basis benefits large developing countries whose populations are likely to stabilize shortly, it does not benefit many developing countries including India. Not much discussion though took place with reference to this choice between two scenario. The possibility of allocating entitlements choosing the base year for population to be the same as the base year for emissions was suggested as a subject of further investigation.

**vi) The over-occupation of carbon space by the developed nations and the means of redressing this inequity is the key issue in any form of the carbon budget approach.**

Various presentations consistently returned to the theme though that the most pressing concern was the over-occupation of carbon space by the developed countries. In a variety of presentations from different viewpoints it was clear that the entitlements of the developed nations were essentially negative. Even with the choice of base year as 1990, as in the German proposal, it was clear that most of the developed nations would have overall only negative entitlements for the future (in terms of averaged annual emissions over the entire time period specified). The proposals made at Copenhagen for a global goal in emissions reduction together with an 80% cut (below 1990 levels) by 2050 by developed nations amounted to a significant loss of carbon space for the rest of the world.

**vii) Feasibility for the entire world and operationalization are important issues.**

On a more general note, the point was made that any approach to burden-sharing in mitigation, including that of carbon budgets, needs to be an approach that is feasible to the entire world. In this context, the issue of whether the proposal is operationalisable is important. Any such proposal also needs to be able to take into account the changing circumstances of different countries.

**viii) Technical issues**

At the technical level, there was some discussion on whether the model suffered from an excess of arbitrariness. However it was clarified that the model allocations were indicative and did not constitute a final allocation. If the model was not prescriptive in the sense of final allocations, then the degrees of parameter freedom in the model need not be considered arbitrary.

Another technical issue was the question of whether the time profile of when emissions happened mattered, and further whether we could reasonably assign budgets when a complicated sum over past emissions and future emissions of carbon dioxide needed to be done, taking into account its lifetime in the atmosphere, etc. It was however clarified that from the viewpoint of climate science, especially the work that the carbon budgets approach relies on, the statement of a global budget such as 1000 Gt of $CO_2$ or 1440 Gt of $CO_2$ (over a specified time period, for keeping temperatures below 2 deg C) takes into account all such effects and that for mitigation policy only the carbon budget matters. Thus every ton of carbon dioxide contributes equally to global warming within the specified time period.

In summing up the impact of the carbon budget approach in climate policy, it was also noted that serious work needs to be done on understanding how the financial and technological transfers that are sought in the carbon budget approach would be utilised. This would further validate the approach. At the same time we need to think of compliance regimes under this approach, how countries could be incentivized to this approach, how specifically transfers could be effected in a carbon budget framework and how the entire approach could be refined to attract the maximum support.

## (b) Carbon Budgets and the Climate Negotiations:

### i) Carbon Budgets and the Shared Vision in Long-Term Co-operative Action

The issue of carbon budgets as a perspective for determining the stand of developing countries in climate negotiations did occasion substantial discussion. At the outset it was noted that equity in terms of equal per capita stock rather than per capita flows provided a guaranteed means of ensuring that all countries would have to undertake some mitigation action in a graduated fashion, especially in order not to exceed the limitations on physical carbon space from the global carbon budget. In this sense, the per capita stock argument provides an `exit' route for the climate issue that is not available with a per capita flow perspective on equity. More concretely it was noted that it is time for the shared vision in long-term cooperation to shift from the perspective of flows to stock. In this context carbon budgets enable assessments of national actions and allow for different pathways. There was broad agreement that carbon budgets allowed for making concrete several specific provisions of the UNFCCC. The need for carbon space (required for developing infrastructure and industry and the provision of energy services) concretizes the provisions for the priority of eradication of poverty and economic and social development for developing countries laid down in the convention.

There was some specific criticism that the model did not explicitly incorporate the criteria of common but differentiated responsibilities and respective capabilities. However, there was general agreement that while the model provided indicative strategies for achieving these aims, the carbon budget approach was a more general framework that explicitly took into account these core principles.

### ii) Carbon Budget and MRV

In general the carbon budget approach provides a definite criterion for burden sharing in mitigation and is firm in safeguarding the global environment through its acceptance of a global carbon budget. It provides for a basis for quantifying and specifying the provisions on finance and technology transfer, gives a definitive basis for judging the adequacy of national actions of all nations and a corresponding basis for undertaking monitoring, reporting and verification (MRV). The last point on the linkage between MRV and a carbon budget approach as a paradigm for equitable access to global atmospheric space that must be in place before MRV can be meaningfully applied was taken up in several interventions.

### iii) Other related issues in climate negotiations

It was also noted that if the carbon budget perspective becomes the key approach in the negotiations, specific clarifications and modifications of India's stand would become necessary. A more proactive stand on plugging LULUCF loopholes and hot air from Annex-I parties would be necessary. India would also need to re-examine its stand on carbon trading, as widespread carbon trading would allow the developed countries to perpetuate their over-occupation of carbon space.

More generally, there was a sharp discussion on whether developing countries need to also have a ``Plan B'' so to speak, that would accommodate a bottoms-up approach to climate mitigation, instead of a top-down, overarching agreement, to which carbon budgets also belonged. In this view, the carbon budgets would have a more limited role as a perspective from which to judge various proposals and commitments. However the majority of participants felt that a so-called ``top-down'' approach will be still the viable way to go forward, especially in the current delicate situation at the climate negotiations. Concern was also expressed whether a carbon budget approach would shift focus from the short-term to the longer-term thus weakening the pressure for immediate action on mitigation.

## (c) Carbon Space as development space and Energy-related issues.

There was broad consensus on the need for adequate carbon space for developing countries especially in order to address the issue of energy access in developing countries with tremendous development deficits. One of the critical issues raised by in the presentations and the discussion was the costs of low-carbon development that will be imposed on the developing nations as a consequence of the lack of adequate physical carbon space for their development (in the sense of not obtaining their fair share of carbon space). It was made evident that the basis for computing this extra cost must be based on the cost of avoided carbon emissions, due to switching from fossil-based emissions, to either nuclear or solar-based generation of power as the source of energy. Such calculations made it clear that the costs for developing countries for a low-carbon pathway were not small, and that developed nations needed to provide adequate financial transfers and suitable forms of technology transfer to enable developing nations to access a low-carbon pathway to development.

## (d) Other issues:

### i) Ethical questions.

A number of other aspects of the carbon budget approach also came up for discussion. Notable among these was the question of the ethical basis of the equal per capita stock principle that is at the heart of the carbon budget proposal. It was emphasised that the argument for carbon budgets must be strengthened by a clear perspective on its ethical foundations and that its proponents need to be able to argue that it is the ethically correct option. The question of what happens to the ``polluter pays principle'' which has been used as the basis for discussions of historical responsibility and whether it is in tension with the ``right to carbon space'' approach that underlies the carbon budget approach was raised. This issue was not further pursued in the discussion. It may be argued that the ``dual'' character of emissions within a carbon budget suggests that the resolution of the tension lies in regarding emissions within a budget as ``right to carbon space'' and emissions beyond those limits as pollution.

### ii) Other Equity-based Proposals:

The conference also heard three reports on equity based proposals. The first was the German budget proposal, the second was the Greenhouse Development Rights (GDR) approach and the third was a comparative survey of various other equity based proposals. It was clarified that equity based proposals fall into two distinct classes, the first based on consideration of per capita emission flows and the second based on per capita accumulated emissions (stock). The German budget proposal was in the second category, though most participants found the choice of base year as 1990 unacceptable. But the several points of contact with the Indian proposal were also clearly interesting. With the respect to GDR, its dependence on a per capita flow principle was noted as well as the possibility that rising capacity (GDP) in the developing world would result in a loss of carbon space. However in general discussion, the possibility of both approaches making contact either in terms of final results or in terms of learning from specific features of either approach was noted.

## (e) An agenda for the future:

The valedictory session provided an opportunity for a general stock-taking of the learnings of the two days of the meeting and the prospects of carrying forward an agenda on the carbon budget. The undertaking of a modeling effort that addressed specific questions determined by the interests of developing countries was specifically commended by some participants.

The idea of taking up the carbon budget approach seriously with the BASIC countries and with the G77+China group was suggested. It was also suggested that India should pro-actively take up the carbon budget perspective on its own also and make a serious intervention in the international debate on equity by suitable means. It was also suggested that a small task force be formed to further explore the prospects of taking the carbon budgets approach forward seriously in the climate negotiations. For equity to be brought to the centre of negotiations, what is required are critical inputs from scientists to negotiators, negotiators' understanding of these inputs and civil society action.

The discussion also revealed a wide range of approval, support or interest in the carbon budget approach. Participants in civil society organisations were distinctly interested in generating momentum on the approach within a broad framework based on equity, while participants from government were also interested in a more detailed evaluation and a prospective agenda for carrying the approach forward. It was also made clear that government would be seriously interested in the results of further academic research on this subject and that they looked forward to the emergence of peer-reviewed research products on this issue and on various aspects of the equity issue in general from India.

The meeting ended with the organisers thanking the various dignitaries, speakers and presenters and participants for their participation and the support and encouragement provided by the Ministry of Environment and Forests, including the Minister in person, the Tata Institute of Social Sciences and the World Wildlife Fund-India.

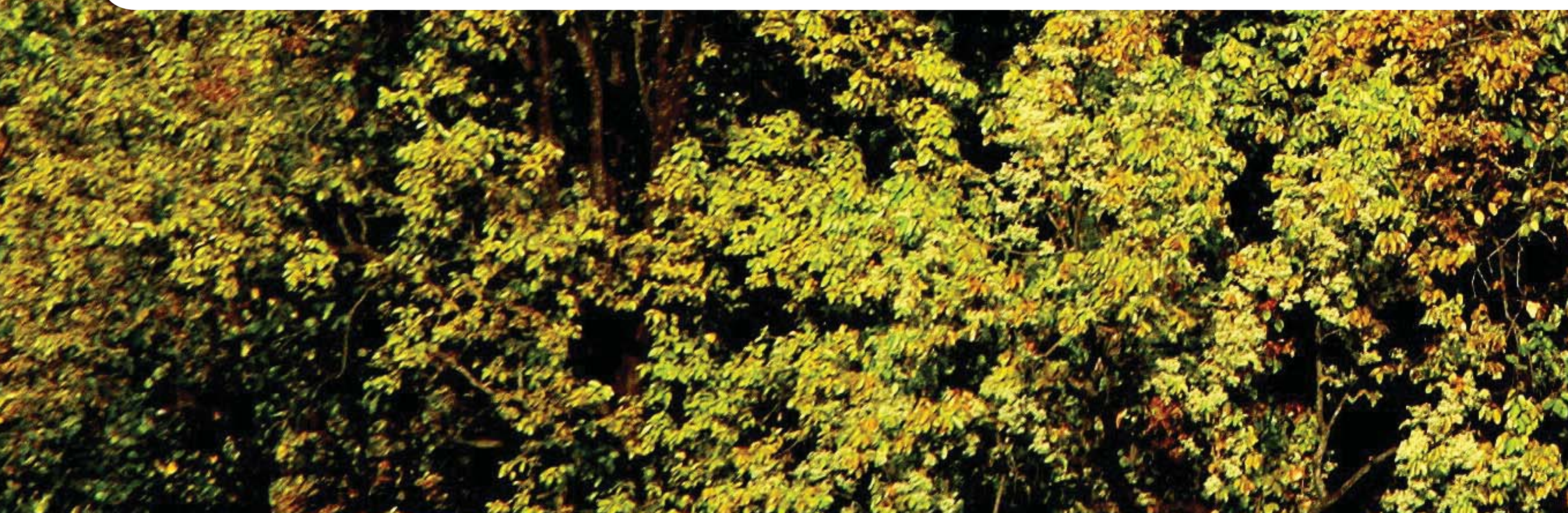
We thank Ms. Himani Phadke for the diligent and useful rapporteuring. The mistakes and shortcomings of the report are the sole responsibility of the Center for Science Technology and Society, School of Habitat Studies, Tata Institute of Social Sciences, Mumbai.

# Global Carbon Budgets and Burden Sharing in Mitigation Actions – Complete Report

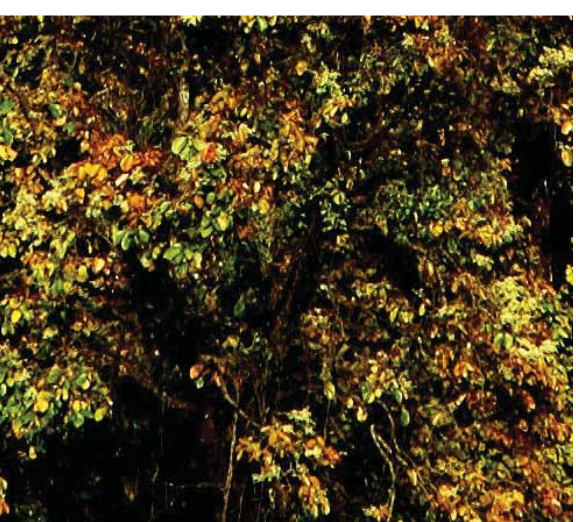

Tejal Kanitkar*
T. Jayaraman*
Mario D'Souza*
Mukul Sanwan**
Prabir Purkayastha***
Rajbans Talwar***
D. Raghunandan****

*Centre for Science, Technology and Society, School of Habitat Studies, Tata Institute of Social Sciences, Mumbai, India
**Formerly Policy Advisor, UNFCCC (1995-2007)
***Delhi Science Forum, New Delhi
****Center for Technology and Development, New Delhi

Address for Correspondence: **Center for Science Technology and Society, Tata Institute of Social Sciences, Deonar, Mumbai 400088, Tel: 022-2552 5372, Email: tjayaraman@tiss.edu**





# 1 Introduction

The development of a simple and straightforward method to deal with the sharing of the burden of mitigation continues to be the key challenge in global climate governance. There have been a number of approaches to this question in the academic and policy literature. However most of these approaches have been dominated by the perception that emissions of greenhouse gases are fundamentally a form of pollution causing environmental damage that must cease at the earliest. This foundational perception has been the basis for the wide-spread view, especially in developed nations, that large emitters, irrespective of whether they are developed or developing nations, must participate in climate change mitigation immediately.

On the other hand, developing countries have, in general, tended to argue from a position that effectively counter-posed environmental concerns to development, while attributing historical responsibility for global warming to the developed nations. From such a point of view, the developing countries' position has tended to appear as an argument for the need to continue polluting as it were, laying the large developing nations in particular open to the charge of being unmindful of the threat of global warming while pursuing a fossil-fuel based development paradigm. However, the developing countries' position, while undoubtedly justified in many ways, has neither fully satisfied the environmentally conscious sections of global public opinion nor has it helped to engage the developed nations on their demand for immediate action by the large developing nations.

But as has been recognized by some[3], the fundamental issue is the one-sided consideration of GHG emissions solely as pollution, without recognizing the dual character of such emissions as a necessary part of development, especially since alternative sources of energy that are not based on fossil fuels, are still not adequate from a techno-economic perspective. Even more importantly, such recognition leads on to a perspective of GHG emissions as utilization of the global atmospheric commons. The basic equity principle that naturally follows from this is that of equal access to the global atmospheric commons for every human being. This principle would carry no particular weight if it were not for the fact that there is a limit to the amount of greenhouse gases that can be placed in the global atmospheric commons by human activity. In this framework, the fair and equitable utilization of the global atmospheric commons imposes a common responsibility on all nations, while providing a clear basis for differentiating responsibilities in terms of the current occupation of this global commons. The global commons perspective also ensures that the burden of seeking non-fossil fuel sources of energy also falls on all nations progressively, as they approach the limits of their share of the global commons.

In this paper we first describe a model that generates different scenarios of the partitioning of the physical global carbon space between different regions/nations. In the second part of the paper, we present the details of indicative strategies for the equitable sharing of the global atmospheric commons, generated using this model, that significantly furthers earlier work both by the authors of this paper[4] and other research groups. We will also show using the model how such strategies provide equity-based benchmarks against which other mitigation proposals can be tested and evaluated.

The paper begins with an account of the basics of the particular version of the carbon budget perspective adopted in this paper. This is followed by a description of the main features of the model for determining the relative share of physical carbon space of various nations and regions within a global carbon budget for the first and second half of this century. This model significantly provides a relatively ``natural'' algorithm of dynamically allocating these shares of the physical carbon space. With these allocations we determine the extent to which various nations are able to reach their entitlement of carbon space.

The paper explores the implications of carbon budgets for developed nations and developing nations, utilizing the United States and the European Union as examples of the first category and China and India as examples of the second. Later sections cover a number of details, including more detailed results for other regions and countries and comparison with some other mitigation (including those based on carbon budgets) proposals. Technical details of the model and detailed tables and charts and figures covering a number of nations are presented in relevant appendices.

# 2 Basics of the Carbon Budget Perspective

We begin by underlining some specific features of the carbon budget perspective that is adopted in this paper as the term carbon budget approach may be subject to other interpretations.

Firstly, all efforts at mitigation must begin with the recognition of the physical constraints imposed by the limits on greenhouse gas emissions into the atmosphere. Economic and other considerations cannot dictate in the first instance how much more humanity can emit into the atmosphere. This task must be left to climate science to determine, based on a determination (a) of the increase in global average surface temperatures that would result from greater concentration of GHGs in the atmosphere, (b) on the impacts of such a temperature increase on the Earth's climate and biosphere and (c) and the consequences of such impacts on human and social well-being.

Secondly, the atmosphere is to be regarded as a global commons. We recognize further that it is a global commons not only from the perspective of pollution, but also from the viewpoint that the sum of greenhouse gas emissions (from the past, present and the future) into the atmosphere constitutes the utilization of a limited but common resource. We will refer to the total allowed emissions for humanity as a whole by the term global carbon budget which will have to be partitioned among all nations. Recognizing that the atmosphere is a global commons also validates equity as the basic rule for the partitioning of global carbon budget.

In this paper we will in particular focus solely on a minimal notion of equity, namely that of equal division of the available global carbon space among all nations based on their respective populations. We note that some equity-based proposals allow for other criteria to modify this bare equity of per capita stock rule, by the inclusion of a floor level of emissions for all nations or allowing for modifications for various regions/nations based on their geographical circumstances . However in this paper we will not attempt to incorporate such criteria, in part because they may tend to dilute the environmental perspective with several socio-economic assumptions.

In what follows we will distinguish between two possible uses of the term carbon space with reference to particular regions/nations. The first is the fair share of global carbon space that is due to various nations for any given time period based on their relative share of the global population. We will use the term entitlement to refer to the emissions that a region/nation is allowed in a given time period. Entitlements for a time period can be negative if a region/nation has over-occupied carbon space beyond its fair share prior to this time period. We will use the term physical carbon space or physical share to refer to the actual emissions that a country can or will undertake. Physical shares of course can never be negative. Negative entitlements cannot be realized physically (except by undertaking activities to promote sinks such as through reforestation) and can only be realized through financial or technology transfers. We emphasise also that global carbon space is always a positive quantity. Zero entitlements or close-to-zero entitlements at any given time imply that a region/nation is at its fair share or close to its fair share respectively

It is of course possible to formulate the issue discussed in the previous paragraph without use of the term negative entitlements as was done in an earlier version of this paper. In such a case we would keep track of the utilization of physical carbon space as well as the over-occupation of the global commons by the developed countries. However the term entitlements and representing over-occupation by negative entitlements clearly drives home the point that the developed nations need to compensate those developing nations that are unable to access their fair share of physical carbon space.

Keeping economic and other allocation criteria out of consideration in the first instance in determining the carbon budget, also assures the relative autonomy of national decision-making with regard to socio-economic policies within the overall global environmental constraint and the particular constraint implied by the carbon budget for that nation. Imposing economic criteria at the outset also imposes many other implicit assumptions in determining the developmental futures of different nations. Economic criteria can be contested much more sharply than physical criteria. It is by now a truism that no single indicator captures the complex relationship between emissions and development adequately even in the present. Considerations for the future are even more beset by uncertainties. Measures such as the Gross Domestic Product have been the subject of much well-known criticism. Other considerations such as the convergence of per capita emissions purely in the domestic consumption sector, for instance, ignore the strong linkages between consumption and production.

However, it is clear that given the current state of development of non-fossil fuel sources of energy, most developing nations have a vital need for physical carbon space, so that they can in the short and medium-term deal with their development requirements in relatively inexpensive fashion. Our results will also show that the fundamental constraints faced by developing nations is such as to preclude any possibility of development based purely on past historical trends in the use of fossil fuels. Conversely, this also implies that advanced industrial nations need also, for considerations of equity, to adopt such new techno-economic paradigms and different growth pathways within such new techno-economic frameworks.

The concept of a carbon budget makes it clear that mitigation action for developed countries cannot be defined solely in terms of milestones in emissions reductions (at the global and regional level) to be achieved in two particular years, say 2020 and 2050, as has become the common practice in climate negotiations. Nor can it be reduced to specifying the peaking year in advance for developing nations. The utilization of a carbon budget over a given time period is determined by the entire trajectory of annual emissions over this same time period. In mathematical terms, the budget amounts to the total area under the curve representing the emissions trajectory.

The carbon budget perspective based on the equity principle of equal per capita share of total carbon space is clearly superior to the equity principle based on equal per capita flows of emissions. While the gross inequalities in per capita emission flows certainly indicate inequitable access to the global atmospheric commons, it does not provide any justification for the continued emissions by the developing countries in order to realize their developmental goals. At the same time it also does not indicate what the contribution of the developing countries will be to mitigation. Thus on both counts, from the point of view of preserving the right to development as well as indicating when the responsibility of participating in mitigation action is to be expected , the equity in per capita flows principle does not provide adequate support to the case of the developing countries.

# 3 Detailed Parameters of the Carbon Budget Proposal

## 1850 or 1970 - Setting the base year

In this detailed formulation we shall focus only on the role of carbon dioxide as the major GHG. We shall ignore other GHGs, leaving them for consideration in a separate note[1] . In accounting for historical carbon dioxide emissions, there is considerable uncertainty in the Land-Use Change and Forestry sector (LUCF), especially with regard to historical data. Thus the total estimate of the gross stock of carbon dioxide emissions into the atmosphere is somewhat uncertain. However the net stock of carbon dioxide in the atmosphere, that is the remnants of the emissions after accounting for the carbon cycle, is a measured quantity. This is currently (up to 2009) 387 ppm, that translates into 824 Gt of carbon. However for computing the current share of various nations or regions to this net stock we shall estimate it using only non-LUCF data for historical emissions from the CAIT tool v. 7.0. Although historical data for LUCF emissions has now been made available by some databases such as the Edgar-Hyde Database (decadal data from 1890 to 1970 and annual data since 1970), the activity error for this data is approximately 100%. Similarly LUCF emissions dataset in the CAIT 6.0 tool (data available only from1990 onwards) has an activity error of 150%. It is clear therefore that including LUCF emissions in estimating the contribution of various nations to the current global net stock of carbon dioxide would introduce significant errors in the calculations. In estimating the contribution of various nations to the current carbon dioxide net stock, we will also make the entirely reasonable and justifiable assumption that the absorption of carbon dioxide is uniform over the Earth's surface irrespective of the region or country from where the emissions take place.

Conventional considerations of historical responsibility for emissions have focused on using 1850 as the base year (the year from which the Industrial Revolution could be considered to be fully underway). However Annex-I countries have disputed this notion of historical responsibility and have argued that absence of scientific knowledge regarding global warming absolves them of historical responsibility from 1850.

However setting a base year for historical responsibility that is substantially later may remove this contentious issue from the discussion. We note that the monitoring of carbon dioxide emissions was fully recognized by the year 1972 in the Stockholm conference on the Human Environment organized by the United Nations[i]. We also note that already prior to this, in 1968, the problem of global warming due to carbon dioxide emissions had been noted at a conference organized by the American Association for the Advancement of Science, in preparation for the 1972 conference[1]. The recently released documents from the Moynihan correspondence[2] during the Nixon administration also demonstrate clearly that the problem of global warming was fully known at the highest levels of the political leadership of the United States. It bears emphasis that at the time global warming was considered a threat by the Nixon administration, since the preliminary assessments of that era tended to have higher damage assessments within shorter time scales than subsequent studies.

Using 1850 as the basis year from which emissions are counted, the developing countries are entitled to an overwhelming share of the carbon space available in the future beyond 2010. Our analysis shows that using 1970 as the basis year also gives a similar

1 We may also note that the issue of measuring non-CO2 GHGs is still under discussion in international climate negotiations and in the IPCC in the discussion track on suitable metrics for global warming. While global warming potentials are the standard in the Kyoto Protocol, the issue of alternative metrics such as global temperature potentials have appeared on the agenda. See for instance the relevant links on the home page of the Intergovernmental Panel on Climate Change (IPCC) at http://www.ipcc.ch and references therein.

result, with developing countries still being entitled to the bulk of the carbon space in the future. This is because the Annex-I countries' continued over-occupation in absolute terms of the total bulk of carbon space has occurred in the period 1970-2009. Accounting only for non-LULUCF emissions, the total gross carbon dioxide stock contributed from 1850-2009 is approximately 332 Gt of C of which only 109 Gt were contributed from 1850-1970. Thus the 1970-2009 contribution to gross stock accounts for the greater share (67.2%) of post-1850 emissions, amounting to 223 Gt of C.

We show in the table and figure below the contribution of different regions and nations to the current stock of carbon dioxide in the atmosphere, using the two different base years, namely 1850 and 1970. We also compare these numbers to the fair share of regions/ countries based on their current population.

1960s, makes it evident that improvements in fuel efficiency and emissions efficiency do not lead to emissions reductions and that the latter requires independent effort in the context of Annex-I nations.

(III) The shift of base year to 1970 does not significantly detract from the basic equity argument of the majority of developing countries for their due share of carbon space. On the one hand the existing carbon dioxide in the atmosphere cannot be removed and hence the shift of base year does not substantially add to the physically usable carbon space that the developing countries could lay claim to. On the other hand, the relatively unchanged figures for the current share of various regions and countries with the new base year suggest that their claim for sufficient carbon space to undertake their development will not be seriously compromised.

**Table 1. Fair and Actual Shares of Carbon Space**

| Regions/Countries | Fair share of Carbon Space (2009 pop.) | Current actual share of Carbon Space (1850 basis) | Current Actual Share of Carbon Space (1970 basis) |
|---|---|---|---|
| | (Based on 2009 pop.) | (1850 basis) | (1970 basis) |
| USA | 5% | 29% | 24% |
| Other Annex-I | 14% | 45% | 41% |
| China | 20% | 10% | 13% |
| India | 17% | 3% | 3% |
| Other Emerging Economies | 15% | 9% | 12% |
| Rest of the World | 29% | 4% | 5% |

From the table it is clear that the figures for the current share of carbon space whether they are based on 1850 or 1970 do differ. However the differences are not so large as to significantly change the broad distribution of responsibility for current stock of atmospheric carbon dioxide in the 1970 basis as compared to 1850. The figures in the table above indicate the following:

(I) The domination of carbon space by the Annex-I beyond their fair share based on their population share is not solely the result of their significantly earlier industrialization. Even if the base year is shifted by 120 years, their domination of carbon space has continued, with very minor modifications. Thus historical responsibility is also current responsibility with base year set as 1970.

(II) Further the determination of the base year as 1970, which is post the major oil-shock of the late

(IV) There is however a loss of ground for a few major developing countries, as it increases their historical contribution to global carbon space, even though a few of them are still below their fair share.. These individual developing countries will also need to implement emissions reduction from business-as-usual and later absolute reduction of emissions, since there is a limit to the quantum of physical carbon space that can be re-allocated from the developed countries to the developing countries. This restriction however is imposed only as it becomes clear that these countries will nevertheless be on course to reach their fair share of carbon space by 2050.

(V) The shift of base year however leaves open the question of whether 1850 could nevertheless be considered as the base year for considerations of financial and technological transfers by the developed nations. We note though that the difference in the negative entitlements of the developed countries for the period 2009-2050 is moderate compared to the overall scale of the negative entitlements.

## The Global Carbon Budget for the period 2009-2050

As we had indicated earlier, climate science must determine the amount of carbon dioxide that can be emitted into the atmosphere. However climate science cannot predict exactly the impact of a given cumulative stock of carbon dioxide emissions on global temperatures. It provides such predictions only in a probabilistic fashion. Thus the global carbon budget for the future is dependent on the degree of risk that the nations of the world are willing to undertake in ensuring that the rise of temperatures due to global warming and the attendant consequences remain within tolerable limits. It is widely accepted across a number of forums, including in the Copenhagen Accord, that the rise of temperatures should not exceed 2 deg. Centigrade over pre-industrial levels. Different climate models however provide a range of temperature increases for a given carbon budget. Hence for a given carbon budget there is a range of probabilities for exceeding a given temperature rise, where this probability refers to the range of different values that various models predict[7] .

Following Meinshausen et al.[5] we note that a carbon budget of 272 Gt of carbon between 2000 and 2050 gives a probability of between 10% and 42% of exceeding a 2 deg C rise in temperature. A carbon budget of 393 Gt of carbon between 2000 and 2050 gives a probability between 29% and 70% of exceeding a 2 deg C rise in temperature. Since emissions from 2000 to 2009 amount to approximately 93 Gt of carbon (including LUCF emissions), it is the remaining amount that is available from 2010 to 2050. We note that it is increasingly unlikely that the budget of 272 Gt of carbon for 2000-2050 will be adhered to. Hence in the calculations presented in this paper we will work with a budget of 393 Gt of carbon for the first half of the 21$^{st}$ century. We may clarify here that considerations of when a particular amount of carbon dioxide was emitted are not relevant in the Meinshausen et al. budget formula. All absorption effects due to the upper and lower ocean, etc. have been factored in and in the final carbon budget figure that is presented every ton of carbon has the same significance for contributing to a rise in temperatures. This scientific view of global carbon budgets clearly provides powerful support to the carbon budget approach to mitigation.

Apart from the fact that 2050 appears in several scientific discussions as the landmark year for bringing global emissions under control, we note that for carbon budget considerations based on 1970 as the base year, 2010 marks a mid-point between 1970 and 2050. We may therefore divide the period 1970-2050 into two, the first until 2010 marked by the historical responsibility of the developed nations and the second dominated by the developing countries' need for carbon space for their growth.

# 4 Modeling the Allocation of the Global Carbon Budget

## General considerations

The essence of the carbon budget perspective is the partitioning of the remaining carbon space among all nations in the first half of this century based on appropriate criteria. We have already indicated that our choice of this principle is the right of all nations to attain their fair share of atmospheric carbon space within the constraint of the global carbon budget. However it is uncontested under the terms of the UNFCCC that Annex-I parties have to take the lead in emissions reduction. This follows in self-evident fashion in the carbon budget approach since the Annex-I countries have already cumulatively taken substantially more than their due share of the atmospheric commons (and thus have negative entitlements). Thus countries with less than their fair share of carbon space are allowed to increase their emissions while Annex-I countries commence immediate reductions. However in a significant departure from usual considerations of equity, emissions reduction would also be implemented for countries provided they have the capability of reaching their fair share by a specified time period.

However these moves, of emissions reduction or allowing rise in emissions, have to take place within the overall global carbon budget constraint, which would ensure that the rise in temperatures (or the corresponding concentration of atmospheric carbon dioxide) does not cross globally agreed limits. Further we will also consider the possibility that countries whose current annual per capita emissions exceed a specified threshold limit have to contribute more towards mitigation action than those with substantially lesser annual per capita emissions.

The exact division of the global carbon budget between different nations depends on how rapidly the developed nations initially cut their emissions since this will determine how much physical carbon space will be available for other nations to realize their entitlement. Similarly, the eventual turnaround of the emissions of the large developing countries, particularly China, from a regime of lowering the emissions rate of growth to one of absolute emissions reduction is also significant. In other words, as the total occupied carbon space expands, there has to be a re-allocation of the share of different nations. This re-allocation should proceed until the developing countries reach as close as possible to their fair share of the total carbon space in the atmosphere.

How do we undertake this re-allocation of carbon space between developed, large developing and other developing nations? One appealing method would be a continuous re-allocation of the carbon space that is freed and made available to those nations/ regions that are in need of it. Such a re-allocation may be termed ``dynamical''. It would also be desirable that this dynamical re-allocation is determined by a small set of parameters so that the re-allocation is determined ``naturally'' by a suitable mathematical algorithm. It would be even more appealing if these common parameters did not use many indicators but only a small set of indicators that applied equally to all countries.

We may contrast this ``dynamical'' method to a ``static'' method wherein the share of each country is effectively determined a priori. Typically this may be done by first specifying precisely how much carbon space would be made available by the developed countries ( either in groups or individually) and then adjusting the parameters of the emissions trajectories of the developing nations so that total emissions are kept within the carbon budget. However the drawback of the static method is that considerable manipulation of the parameters of individual emissions trajectories of the developing countries is required in order to ensure that the global carbon budget is adhered to. In this sense, the static method is also ``unnatural'' since it requires several parameters, that have to be individually adjusted, to suitably model the emissions trajectories of different countries.

In practice we use both methods of allocation of carbon space. The dynamical model is more suitable for considering situations where there is coordinated action (whether of low ambition or high ambition) by all countries. The static model however is more suitable in studying situations where the developed nations unilaterally engage in mitigation action of low ambition, leaving the developing nations to make do with the remainder of the carbon space, under whatever scheme of mutual allocation that they may choose.

## Modeling Details

We implement the dynamical model as a 16 region[2] GAMS (General Algebraic Modeling System) code with an objective function that can have the following elements: (a) minimizing the deviation from the fair share of global stock for all countries and regions; (b) maintaining the total emissions within a global carbon budget and minimizing deviations from this budget and (c) minimizing the deviations from specified limits for per capita emissions (the word deviation specifically implies 'negative deviations' e.g. deviation above fair share of carbon stock or above the global carbon budget is penalized). The emissions trajectories are determined within these constraints. In the full final form of the objective function, constraints relating to global stock and the budget carry equal weight while the current flow of emissions carries lesser weight. Since the problem is one of continuous re-allocation of carbon space, the resulting optimization problem is non-linear.

The global budget is divided into a budget for the period 2010-2050 and another budget for the period 2050-2100. In the model, the period from 2010 to 2050 is divided into three time periods. For each of these time periods, the maximum annual rate of emissions growth allowed as well as the maximum annual rate of reduction in emissions are specified for milestone years marking the end of each time period. It must be emphasized that these rates are common to all countries and regions. However the actual emissions trajectories, namely the increase or reduction of emissions of various countries are determined self-consistently by the GAMS optimization code. In either case, all countries are required to cut emissions after 2050, and for the period 2050-2100, the upper and lower bounds on emissions growth refer only to emissions reduction, but at different rates.

In general, when the code picks the rate for the emissions reduction of developed nations, the choice typically tends to saturate the lower bound for emissions reduction. For the developing countries they may increase their rate of growth of emissions, reduce their rate of growth of emissions or absolutely reduce their emissions depending on the time period and their distance from their fair share of carbon space and to a lesser extent on their current emissions. The global carbon budget constraint is implemented as a soft constraint through the use of weights in the objective function. As a consequence, the global carbon budget may not be exactly adhered to and the actual emissions trajectories when summed up would lead to a mild violation of the carbon budget.

The model produces as output the emissions trajectories, namely the annual quantum of carbon dioxide emissions, for every year up to 2100, within an overall budget. Adding the projected annual emissions from 2010 to 2050 for any country or region gives its share of the total carbon budget. A further detailed description of the model and the relevant mathematical details are provided in an appendix to this note.

For the static model we also have a GAMS code that is however posed as a linear optimization problem. In this model, the objective function is again similar in character to that of the dynamical model. However the emissions trajectories of different countries are specified a priori. The parameters of these trajectories are then adjusted to ensure that global carbon budget is adhered to as required. In this paper, we will mostly use the dynamical model. However some results of the static model will be presented in the appendix.

2 The model consists of 12 countries and 4 regions. The details are given in Appendix-I of this paper

# 5 Model Results and Their Implications

## The impact of a global carbon budget

In this section we will discuss primarily results that use 1970 as the base year but will also present some results with 1850 as base year for comparison. For comparing per capita emissions we will use both population figures for 2009 as well as moving population figures. However projections for change in population are available only up to 2050.

In what follows we use the term entitlements to refer to the amount of carbon space to which regions/ nations have a right. We use the term physical carbon space or physical carbon budget in its obvious meaning. If a nation emits more than its fair share thus over-occupying the global commons in a given time period, then it would have negative entitlements until its cumulative emissions come back to its fair share later.

The projected values for emissions consist of emissions from both the LUCF and non-LUCF sectors. Therefore, reduction or growth shown in these results for each country/region can be in both sectors. A reasonable assumption is made that each country/region can allocate their mitigation burden to either sector.

We first compare the consequences of the model for four different scenarios:

I) Scenario I – This scenario has only the objective of achieving a fair share of the global stock for all regions. Countries with a current share of the global stock that is greater than their fair share have to cut their emissions while those below their fair share can increase emissions.

II) Scenario II - In this scenario achieving a fair share of global stock remains the main objective but there is a penalty on countries with per capita emissions above specified limits in each time period.

III) Scenario III – This scenario has the objective of achieving a fair share of total carbon space within the constraint of a global carbon budget of 1440 Gt of carbon dioxide from 2000-2050.

IV) Scenario IV - In this scenario the objective of achieving a fair share of the global carbon space is combined with a global carbon budget (1440 Gt of carbon dioxide from 2000 to 2050) as well as a penalty on annual per capita emissions beyond specified limits.

The maximum allowed annual growth rates in emissions and the maximum annual reductions in emissions in specific milestone years are given in Table 2. Since increase in emissions is contemplated only for developing countries (according to the UNFCCC emissions from developed countries should have peaked at 1990 levels by the year 2000), the upper bound is written as a multiple of the annual growth rate in emissions in the year 2009. Note that the upper bound on rate of change of emissions varies for each region or country and is written as a percentage of their corresponding growth in emissions in the year 2009. For the milestone year of 2100 alone the upper bound is an absolute rate of reduction in emissions.

**Table 2. Maximum and Minimum Annual Rates of Change of Emissions in Milestone Years**

| | 2020 | 2030 | 2050 | 2100 |
|---|---|---|---|---|
| Lower bound on rate of change of annual emissions | -12.5% | -9% | -8% | -10% |
| Upper bound on rate of change of annual emissions (**with respect to growth rate in 2009**) – Option A | 180% | 150% | 5% | -6%[3] |
| Upper bound on rate of change of annual emissions (**with respect to growth rate in 2009**) – Option B | 180% | 200% | 300% | -6% |
| Upper bound on rate of change of annual emissions (**with respect to growth rate in 2009**) – Option C | 180% | 180% | 180% | -6% |

3 This number is directly the annual rate of reduction in emissions.

| Table 3. Total Carbon Space Utilized in Each Scenario | | |
|---|---|---|
| **Scenarios** | **Total carbon space utilized for the period 2000-2050 (GtCO2) Option A** | **Total carbon space utilized for the period 2000-2050 (GtCO2)- Option B** |
| I - Achieving equitable share of carbon space without any other constraint | 1702 | 1848 |
| II - Achieving equitable share of carbon space with penalty for current per capita emissions above specified limits | 1688 | 1828 |
| III - Achieving equitable carbon space within a global carbon budget (1440 Gt CO2 for 2000-2050) | 1444 | 1444 |
| IV- Achieving equitable share of carbon space within a global carbon budget (1440 Gt CO2 for 2000-2050) and with penalty for current per capita emissions above specified limits | 1434 | 1434 |

The contribution to global stock from all emissions for the four scenarios explained above, using Option A and B from Table 2 is given in Table 3. Even though Scenarios I and II do not have a carbon budget we will determine the actual carbon space utilized in these scenarios. Scenarios III and IV do have a carbon budget but nevertheless the actual utilization of carbon space needs to be determined.

The close similarity in the budgets for Scenarios I and II and in the budgets for Scenarios III and IV are a consequence of our assigning equal weights to attaining fair share of carbon space and the global carbon budget and a lesser weight to per capita emissions above a specified threshold. In Scenarios I and II, in the absence of a carbon budget, emissions may still grow beyond 2050 to allow for all countries to reach their fair share. However within a carbon budget such unlimited growth is clearly untenable, allowing for a budget of only about 220 Gt of CO2 for 2051-2100.

In the Table 4 shown below, we first present the share of the carbon budget accruing to different regions and countries in the various scenarios. We present both the absolute quantum of allowed emissions as well as the relative share of each region in the carbon flows for 2010-2050.

| Table 4. Share of Carbon Budget between 2010 and 2050 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Scenarios** | **1850 Basis** | | | | | | | |
| | **USA** | | **EU** | | **China** | | **India** | |
| | Stock (GtC) | % Contribution | Stock (GtC) | % Contribution | Stock (GtC) | % Contribution | Stock (GtC) | % Contribution |
| I | 18.41 | 5% | 14.38 | 4% | 95.45 | 26% | 70.28 | 19% |
| II | 18.41 | 5% | 14.38 | 4% | 94.56 | 26% | 69.95 | 19% |
| III | 18.41 | 6% | 14.38 | 5% | 79.52 | 26% | 40.17 | 13% |
| IV | 18.41 | 6% | 14.38 | 5% | 79.08 | 27% | 53.43 | 18% |
| **Scenarios** | **1970 Basis** | | | | | | | |
| | **USA** | | **EU** | | **China** | | **India** | |
| | Stock (GtC) | % Contribution | Stock (GtC) | % Contribution | Stock (GtC) | % Contribution | Stock (GtC) | % Contribution |
| I | 18.41 | 6% | 14.38 | 5% | 69.28 | 23% | 60.02 | 20% |
| II | 18.41 | 6% | 14.38 | 5% | 71.37 | 24% | 57.39 | 19% |

The figures in the table above need an important clarification. It is clear that in the 1850 basis, China (and other Emerging Economies, bar India) receives a greater share of the future carbon budget than in the 1970 basis. This is because in the former, China deviates more from its fair share of the total global carbon space and thus is allowed to increase emissions. However within a total carbon budget as in Scenarios III and IV this increase has to be made good by some other region/nation, which is achieved by a lesser allocation to India (and the Rest of the World). It cannot be made good by the developed countries as they are already cutting emissions sharply. However in the 1970 basis, China (and other Emerging Economies) is closer to its fair share and thus more is available for India (and the RoTW). It must be emphasized that this pressure on the developing countries as a whole to divide the remaining carbon space between them is a consequence of the historical over-occupation of the global atmospheric commons by the developed countries.

This raises two critical issues. The first is the implications of this over-occupation by the developed nations for the carbon space entitlement of developing nations. Within a fixed global carbon budget, preserving the carbon space entitlements of developing nations implies negative entitlements for the developed nations in the future.

With 1850 as the base year for accounting for responsibility for emissions we find that the extent of over-occupation of carbon space by the developed nations is such that they will have only negative entitlements to carbon space in absolute and relative terms until 2050 and beyond. This implies that despite any scheme of the redistribution of physical carbon space, especially after accounting for a global carbon budget, developing countries will not realize their full entitlement by 2050. The bulk of developing countries will fall short of their entitlement. Zero entitlements or close-to-zero entitlements at any given time imply that a region/nation is at its fair share or close to its fair share respectively.

**Table 5. Total and Current Entitlements for Each Country/Region (1850 Basis)**

| 1850 Basis | Total Entitlement between 1850-2050 (Based on 2009 Population and a 300 GtC Carbon Budget between 2010-2050) | Current Contribution to Carbon Stock (1850-2009) | Total Entitlements (2009 onwards) |
|---|---|---|---|
| | GtC | GtC | GtC |
| **Annex-I** | 117.99 | 245.34 | -127.36 |
| **China** | 123.69 | 33.09 | 90.60 |
| **India** | 110.00 | 8.66 | 101.33 |
| **Rest of the World** | 280.32 | 44.90 | 235.42 |

**Table 6. Entitlements in 2050 for Two Redistribution Schemes* (1850 Basis)**

| 1850 Basis | Physical Carbon budget between 2009-2050 in the TISS-DSF Model (Option A1*) | Total Entitlement (2050) | Physical Carbon budget between 2009-2050 in the TISS-DSF Model (Option A2**) | Total Entitlement (2050) |
|---|---|---|---|---|
| | GtC | GtC | GtC | GtC |
| **Annex-I** | 50.18 | -177.54 | 39.60 | -166.96 |
| **China** | 79.08 | 11.52 | 79.18 | 11.42 |
| **India** | 53.43 | 47.90 | 57.39 | 43.94 |
| **Rest of the World** | 115.50 | 119.92 | 118.39 | 117.02 |

**A1: Countries above their fair share of carbon stock reduce emissions by 48% of 1990 levels by 2020 and 97% of 1990 levels by 2050*

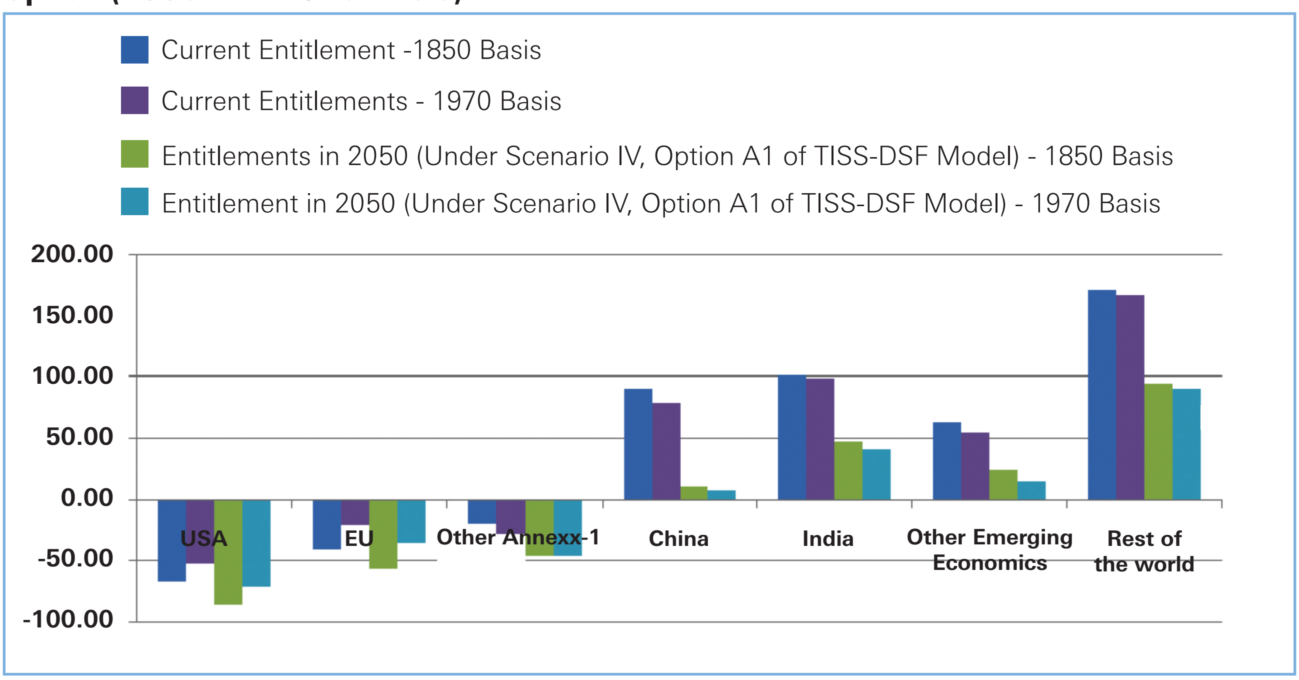
***A2: Countries above their fair share of carbon stock reduce emissions by 63% of 1990 levels by 2020 and 99% of 1990 levels by 2050.*

| Table 7. Total and Current Entitlements for Each Country/Region (1970 Basis) | | | |
|---|---|---|---|
| 1970 Basis | Total Entitlement between 1970-2050 (Based on 2009 Population and a 300 GtC Carbon Budget between 2010-2050) | Current Contribution to Historical Carbon Stock (1970-2009) | Total Entitlements (2009 onwards) |
| | GtC | GtC | GtC |
| Annex-I | 117.99 | 218.37 | -100.38 |
| China | 123.69 | 44.72 | 78.97 |
| India | 110.00 | 10.83 | 99.17 |
| Rest of the World | 280.32 | 58.08 | 222.24 |

| Table 8. Entitlements in 2050 for Two Redistribution Schemes* (1970 Basis) | | | | |
|---|---|---|---|---|
| 1970 Basis | Physical Carbon budget between 2009-2050 in the TISS-DSF Model (Option A1*) | Total Entitlement (2050) | Physical Carbon budget between 2009-2050 in the TISS-DSF Model (Option A2*) | Total Entitlement (2050) |
| | GtC | GtC | GtC | GtC |
| **Annex-I** | 50.18 | -150.56 | 39.60 | -139.98 |
| **China** | 71.37 | 7.61 | 69.89 | 9.08 |
| **India** | 57.39 | 41.78 | 58.47 | 40.69 |
| **Rest of the World** | 115.61 | 106.63 | 117.86 | 104.38 |

Figure 1

**Current and Future Entitlements (Under Scenario-IV, Option A1 and A2) to Carbon Space (1850 and 1970 Basis)**




The negative entitlements that accrue to the developed countries provides a natural basis for considerations of the quantum of financial transfers and the extent of technological transfers from the global North to the South, apart from the claims of the South on the question of adaptation.

## Global considerations – equity is feasible

The evolution of total global emissions in Scenario IV of our 16-region model is displayed in the table:

**Table 9. Global Emissions Reduction in Milestone Years (%)**

| Global Cuts | 2009 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| As a % of 1990 | -33%* | -9%* | 17% | 48% |
| As a % of 2005 | -10%* | 10% | 31% | 57% |
| As a % of 2009 | 0% | 18% | 37% | 61% |

**The negative numbers denote an increase in emissions with respect to the base year with which it is being compared*

It is evident that mitigation action at the global level is not extraordinarily higher than other proposals in the carbon budget approach, but the crucial difference lies in the relative distribution of the burden.

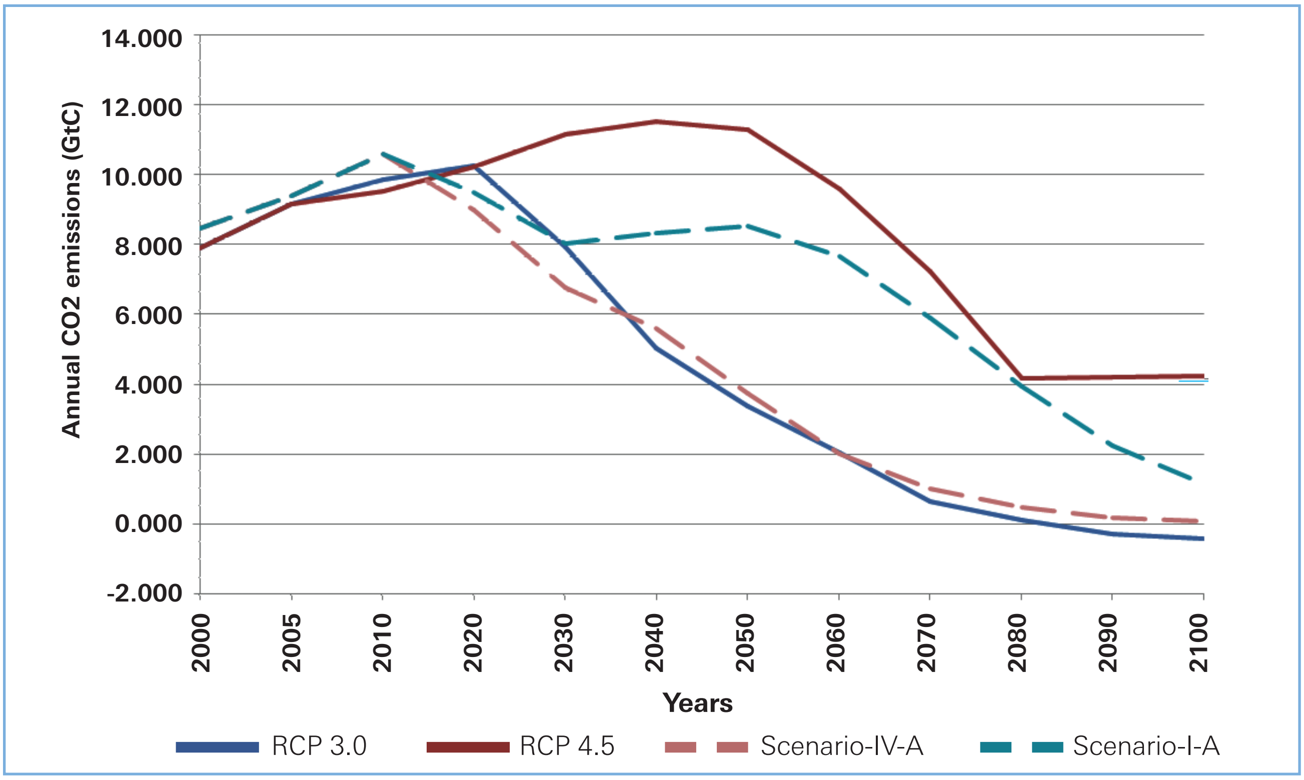
It is extremely interesting to compare the global emissions trajectory with the emissions trajectories in the scenarios that are being developed for the Fifth Assessment Report (AR5) of the IPCC. These scenarios, labeled RCPs (Representative Concentration Pathways), have been developed as a tool for integrated assessment modeling in the work of AR5[4].

We compare in the chart below the global emissions trajectories for Scenario I (Option A) and Scenario IV (Option A) with RCP 4.5 and RCP 3 (the numbers labelling the RCP refer to the radiative forcing in watts/square meter in the year 2100 in the relevant scenario). It is striking that even Scenario I that focuses only on attaining fair share lies below the trajectory of RCP 4.5 and above the RCP 3 trajectory. We find also that Scenario IV virtually follows the same trajectory for the global case as RCP 3. Figure 10 shows the occupation of the global carbon space by 2100 for all regions against their fair share of this space. The conclusion from these observations is that equity (with the qualifications that we attach) is a feasible proposition, and not, as has been often caricatured, a plea for the right to unrestrained emissions.

4 For further details on RCPs including introductory material and detailed explanations, see for instance the material available at http://www.iamconsortium.org.

Figure 2

**Comparison of TISS-DSF Model (Scenarios–I-A and IV-A, Base Year-1850) and Representative Concentration Pathways**




We also compare in the table below further (using MAGICC 5.3[5]) the concentration and temperature increases for the two RCPs as well as Scenario I-A and Scenario IV-A. Using the work of Meinshausen et.al7 we also estimate the probability range for crossing 2 deg. Centigrade. Of course as we have noted earlier, the 272 Gt of C target that would have a lower probability of crossing 2 deg thresholds seems out of reach.

**Table 10. Comparison Between RCPs and Scenarios 1 and IV**

| | CO2 concentration in 2100 (ppm) | Temperature rise in 2100 relative to 1765 (°C) | Probability for exceeding 2 °C | |
|---|---|---|---|---|
| | | | Illustrative result | Range |
| RCP 3 | 403.2 | 1.65 | | |
| RCP 4.5 | 524.6 | 2.37 | | |
| Scenario I-A | 468.6 | 2.06 | 64% | 41% to 81% |
| Scenario IV-A | 406.2 | 1.66 | 49% | 28% to 68% |

5 We acknowledge the use of MAGICC 5.3 downloaded from http://www.cgd.ucar.edu/cas/wigley/magicc. We use the default ``model parameters'' setting in the software without alteration.

## Burden Sharing in Mitigation Actions

We now turn to comparing the corresponding mitigation burden for these regions/countries, viz. United States, European Union, China and India in these different runs. For the two Annex-I regions, the mitigation burden is given in terms of actual reduction in annual emissions from the level of annual emissions in 1990 as well as the deviation of annual emissions from the projected emissions at current rates of growth.

Note that since the Annex-I countries have to cut deeply in any scenario there is little difference between the emissions reductions in the various scenarios.

As discussed earlier the model allocates a carbon budget to each region based on whether its current contribution to the atmospheric stock of carbon is below or above fair share. However the model in its current form does not clearly show the variety of emissions trajectories that are compatible with this carbon budget and provides only an indicative trajectory. We emphasize that within the carbon budget there is considerable scope for national autonomy in decision-making in determining the emissions trajectory of individual nations. Once the physical share of these countries in the global carbon budget is established it is however open to them to reshape their real emissions trajectories in accordance with their national circumstances, provided they stay within their share of global carbon budget by 2050. Thus developing countries will have some flexibility in timing their peaking years and the reduction in emissions to be specified in milestone years, and need not all follow identical trends. This flexibility is however not indefinite, especially if we are looking for realistic emissions trajectories. This flexibility is also obviously less for developing countries that are close to their fair share and have high rates of emissions today.

**Table 11. Annual Emissions in Milestone Years for USA and EU (%)**

| | | Annual emissions as % of 1990 emissions | | | | Annual emissions as a percentage of projected emissions at current rate of growth | | | |
|---|---|---|---|---|---|---|---|---|---|
| Scenarios | Country | 2009 | 2020 | 2030 | 2050 | 2009 | 2020 | 2030 | 2050 |
| I-IV | USA | 119% | 59% | 18% | 3% | 100% | 42% | 15% | 2% |
| | EU | 100% | 50% | 15% | 3% | 100.% | 42% | 14% | 2% |

However, as developed countries are already above their fair share and have to start reduction in absolute emissions immediately, there is no alternative to immediate and sharp cuts by them. The only variation in the trajectories of the developed countries can come from different estimates of reductions that they can reasonably undertake. For example, the two different trajectories obtained from the recommendations of the IPCC AR4 and the Greenhouse Development Framework (GDR).

In the charts below we show the indicative as well as alternative emissions trajectories (for the same national budgets) for US and China.

Figure 3

**Emission Trajectories for USA**

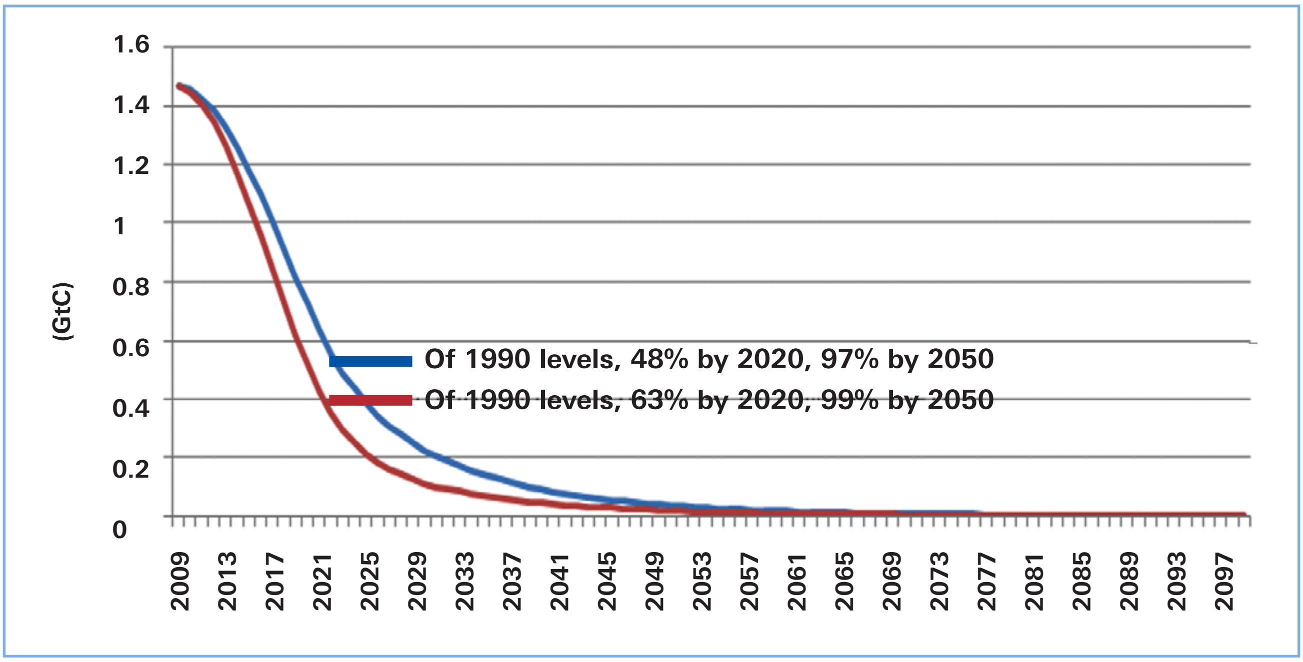
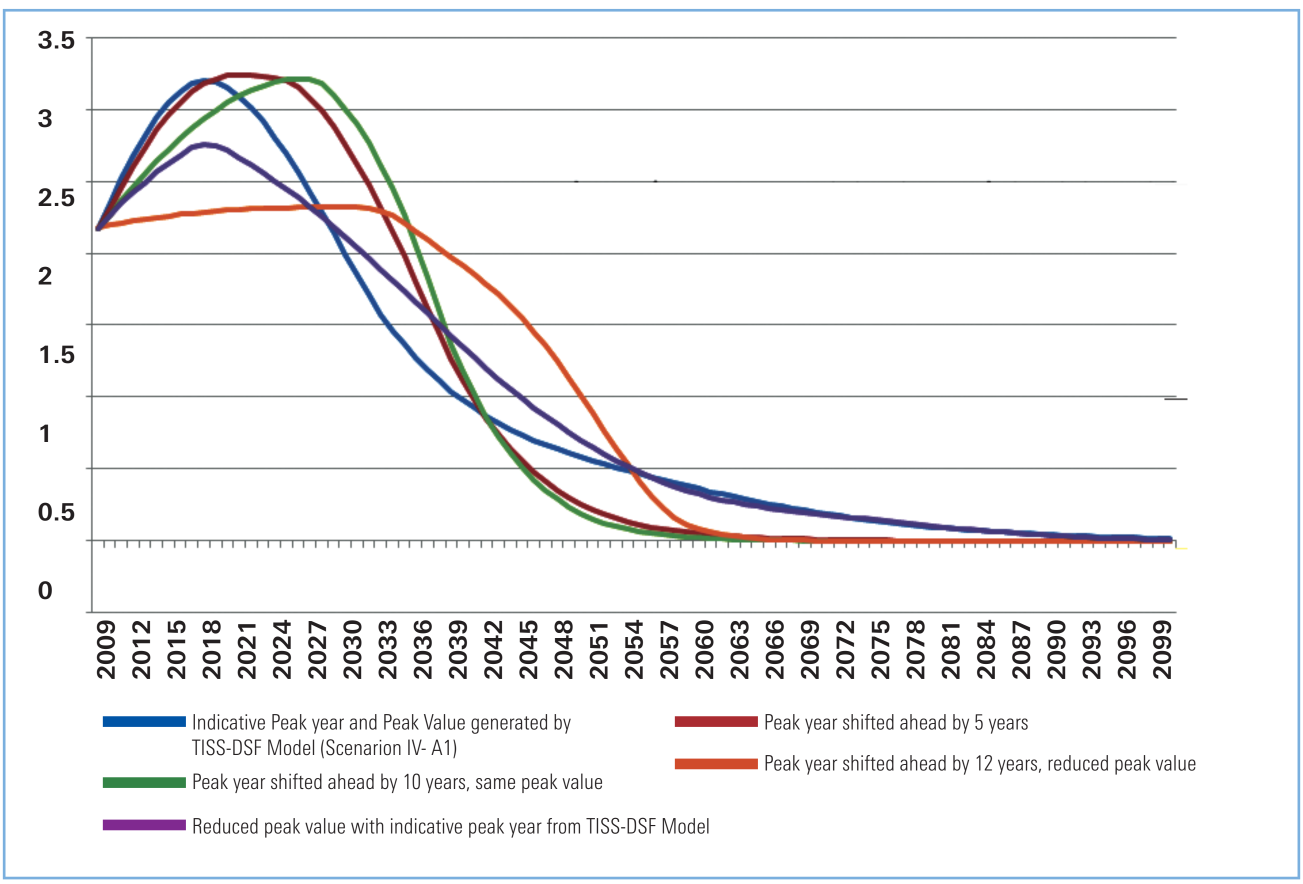



Figure 4

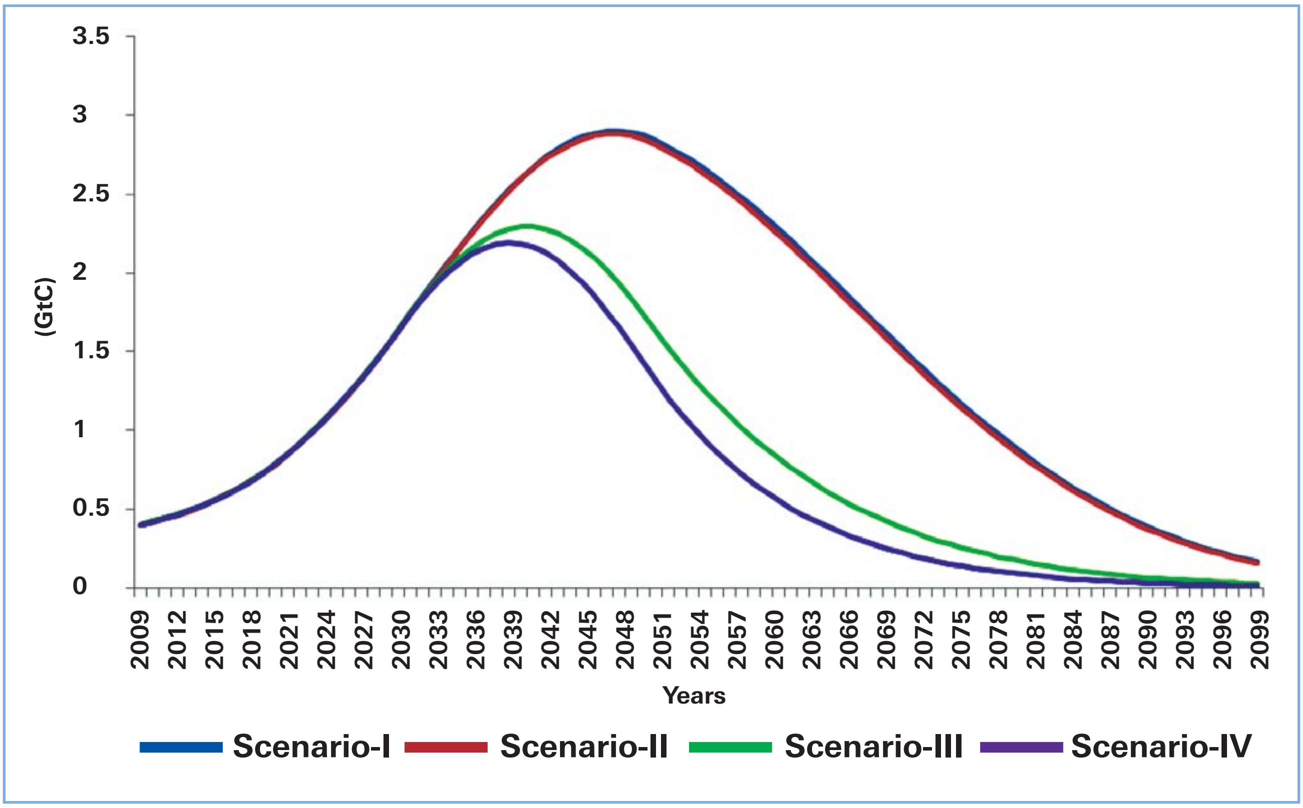
**Emission Trajectories for China for a Budget of 89 GtC between 2010 and 2050**



However the indicative trajectories produced by the model are useful in graphically or visually illustrating the impact of different scenarios for the same region/ nation. For instance, the trajectories for Scenario-I through IV for India makes it strikingly clear that the carbon budget approach convincingly highlights the loss of carbon space for India due to the global environmental constraint, as indeed for all other developing countries. These trajectories are obviously not the real path that India's emissions will be constrained to follow even with the same budgets.

Figure 5. Emission Trajectories for India

**LULUCF +Non-LULUCF Emission Trajectories for India (1970 Basis)**




In the case of US and the EU (and other Annex-I countries) the four scenarios do not differ very much as they are in any case bound to cut heavily. On the other hand, for developing countries, it makes a substantial difference whether a global carbon budget is imposed or not. The necessity of a global carbon budget takes away from the carbon space due to them on equity considerations.

## Per Capita Emission Trajectories

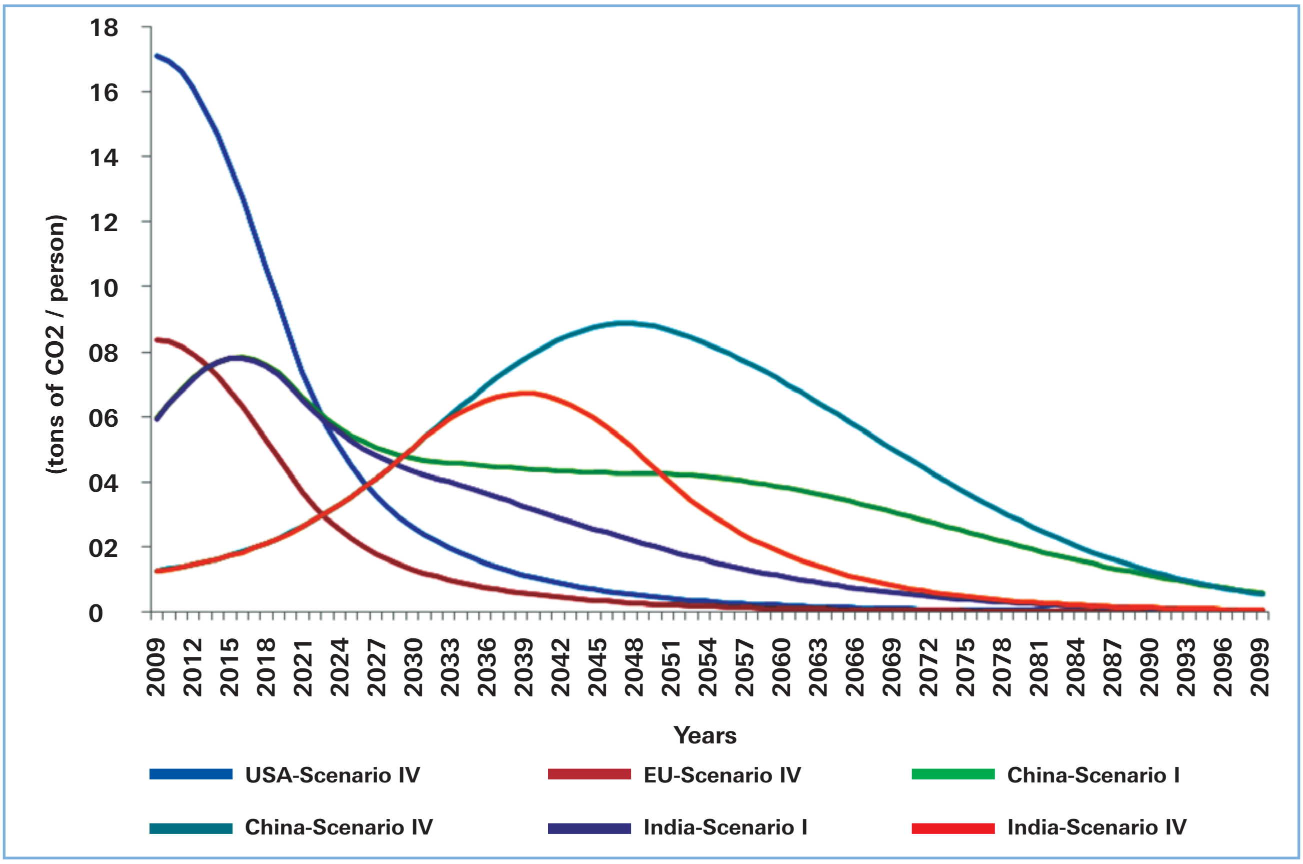
We can reexamine the questions of per capita emissions within the scope of these various scenarios.

We show below the indicative trajectories for per capita emissions trajectories for EU, USA, China and India, with the assumption of constant 2009 population for two different scenarios. For the case of the USA and the EU it is sufficient to plot only the case of Scenario IV as all other scenarios are virtually identical.

But in the case of China and India we will plot two different scenarios, Scenario I and Scenario IV to illustrate the difference in per capita emissions. Even though the trajectories are indicative, they are useful for comparing India or China with respect to US or the EU, since the trajectories of the latter have no flexibility.

The carbon budget perspective makes it clear, as evident from the figure, that it is permissible to allow per capita emissions to converge only much later, towards the end of this century. India's commitment of keeping per capita emissions below that of the developed nations is particularly counter-productive as it surrenders valuable carbon space if the developed nations are prepared to cut their emissions sharply. Equally, India would lose carbon space again if India were able to maintain its commitment due to the Annex-I countries maintaining their emissions at such a high level that their per capita emissions always remained above India's.

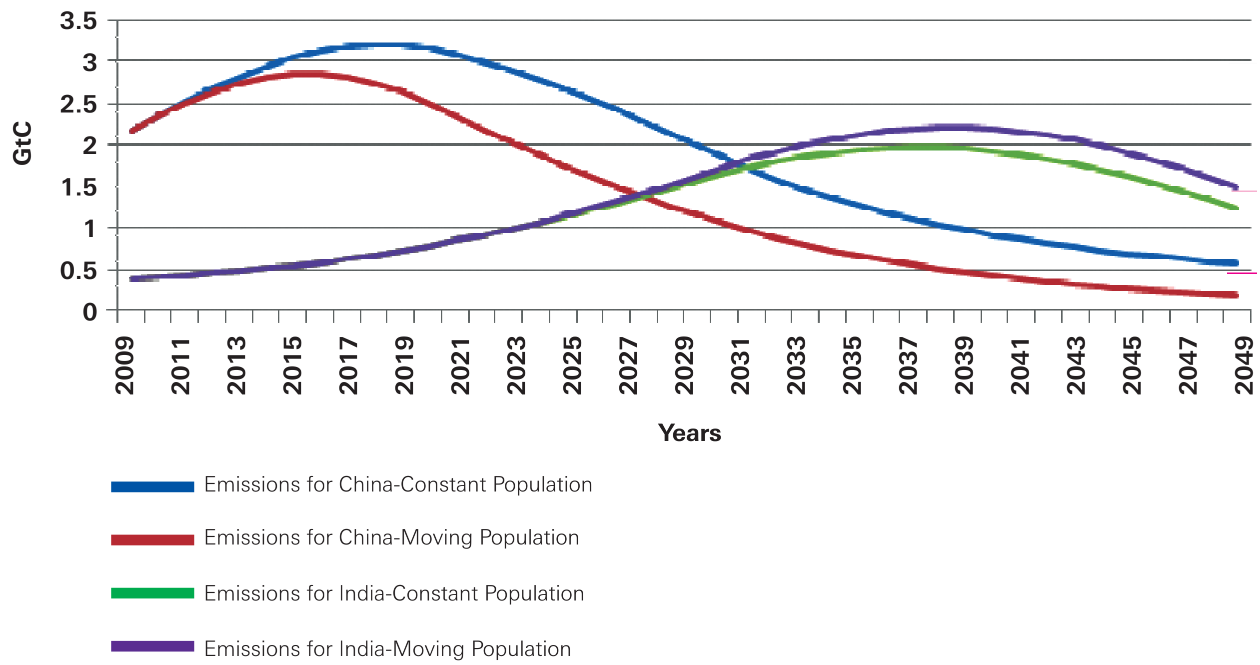
Figure 6
**Indicative Per capita Emissions Trajectories**




Note that these per capita emissions are based on constant population figures. However if we account for projected increases in population[6] figures then the figure above is modified as follows:

6 The population figures from are taken from the UN Population Division available here: http://esa.un.org/unpp/index.asp

Figure 7
**Indicative Emissions Trajectories for China and India – Constant and Moving Population**




While changing the population figures to projected populations it is clear that the per capita emissions figure changes significantly for China and to a lesser extent for India. While India gains a higher carbon budget with moving population inputs, China actually has to give up some of its share to other developing countries with higher population growth rates. While we may use the constant 2009 population figures for computing the fair share of carbon space, it is clear that estimating per capita emissions in the future with constant 2009 population figures would leave some large developing countries open to serious loss of negotiating space. With moving population figures, the peak in per capita emissions for India is only slightly above what is expected to be the maximum per capita emissions in the future as projected by other techniques. The difference between using constant 2009 population figures and moving population figures is important also for other developing countries apart from China and India.

# 6 Comparisons with Other Approaches

In this section we present a brief overview of some comparisons with other approaches to burden sharing in mitigation, some of which are based on climate justice considerations, with or without a carbon budget as its basis. In some of these approaches there is no explicit reference to a carbon budget, nor do carbon budget considerations appear in any central manner. However in so far as these approaches determine the annual emissions of carbon dioxide for several years, they provide emissions trajectories that may be compared to the approach of this paper.

From this point of view, there is a carbon budget prescription underlying any mitigation proposal, whether explicitly realised or not. The details of such proposals may be considered to be a prescription for how the carbon space is to be partitioned among different regions/countries. Comparing various mitigation proposals from this point of view then provides a relatively objective account of their implications, free of the burden of pronouncing on the validity of various economic and other assumptions.

To cite an example, we consider a comparison of one specific carbon budget proposal made by the German Advisory Council for Global Change and the 1970 basis model presented here. There are some significant similarities between the general form of that proposal and our considerations here. However the most significant difference is the non-consideration of historical responsibility in the actual details of the carbon budgeting that relies exclusively on a fair share of the emissions between 2000 and 2050. As a consequence the classification of regions and groupings between our considerations and that of the German proposal are very different as a result of which several developing nations are distributed across what is referred to as Group 1 and Group 2 in that proposal. A second significant difference is in the actual budget that is tailored to 1160 Gt of CO2 between 2000 and 2050. A third significant difference is the assumption of linear reduction in emissions over the budgeting period. But a significant point of concurrence is the recognition of the over-occupation of the commons by the developed countries and

**Table 11. Comparison of Physical Carbon Space for various countries/regions between 2010 and 2050, between the "German" Proposal and the Runs presented in this Paper**

| | German Proposal | 1000 GtCO2; 1850 | 1440 GtCO2; 1850 | 1440 GtCO2; 1970 |
|---|---|---|---|---|
| USA | 35 | 67.50 | 67.50 | 67.50 |
| EU | 54 | 52.74 | 52.74 | 52.74 |
| Russian Federation | 15 | 22.29 | 22.29 | 22.29 |
| Japan | 14 | 16.20 | 16.20 | 16.20 |
| Australia | | 5.90 | 5.90 | 5.90 |
| Canada | | 7.85 | 7.85 | 7.85 |
| Other AnnexI | | 11.53 | 11.53 | 11.53 |
| China | 148 | 198.74 | 289.97 | 262.11 |
| India | 133 | 140.68 | 193.53 | 210.43 |
| Brazil | 21 | 20.33 | 21.48 | 29.60 |
| South Africa | | 5.61 | 5.61 | 5.61 |
| Indonesia | 25 | 39.32 | 38.32 | 47.74 |
| Mexico | 12 | 7.61 | 7.61 | 9.52 |
| South Korea | | 6.84 | 6.84 | 6.84 |
| Other EE | | 46.17 | 58.69 | 44.96 |
| RotW | | 115.09 | 278.35 | 279.17 |

the consequent need for $CO_2$ emissions from these countries to drop to virtually zero in rapid fashion. However the real test is the actual budget allocation and we present below a comparison of the ``German'' proposal and our 1000 Gt $CO_2$ and 1440 $CO_2$ budget runs.

It is clear that the German proposal places tighter restrictions on those whose current per capita emissions are high (except the EU as a whole). For those other nations that have low current per capita emissions, the German proposal matches fairly well with our 1000 Gt $CO_2$ computations.

In similar fashion, we can use the linear GAMS model to simulate the effect of specific emission reduction or carbon budget proposals and compare them to our model predictions. We are thus able to compare in fact a range of other proposals. We show such comparisons for the US, EU, China and India in the charts that follow.

In general, we find that the GDR (Greenhouse Development Rights) proposal has the sharpest reductions for Annex-I countries more than provided for in our model. However it also allows for much less carbon space for the developing countries. Undoubtedly also the reliance in part on GDP as a measure of capability for emissions reduction is at odds with our basic approach.

Figure 8

**Comparison of Proposals for China**

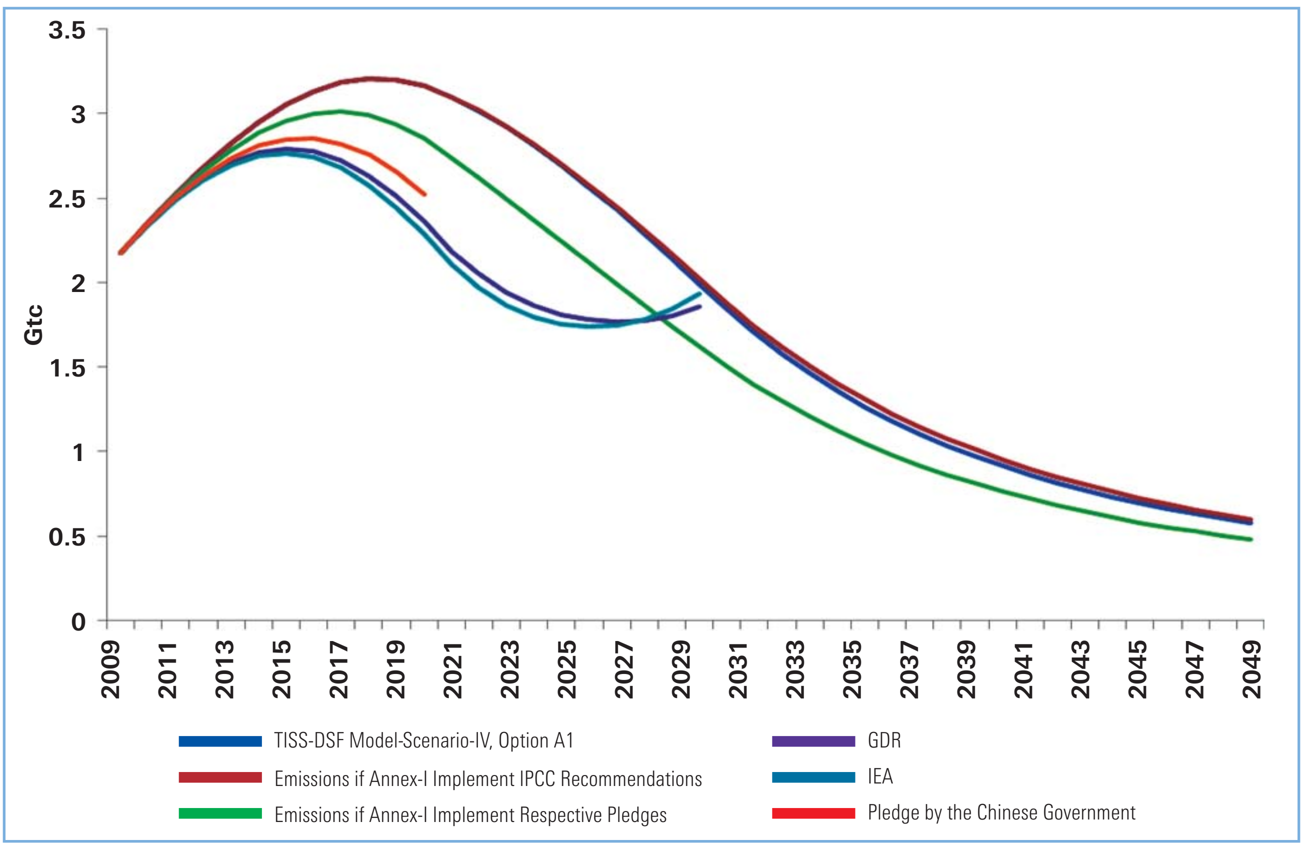


Figure 9

**Comparison of Proposals for India**

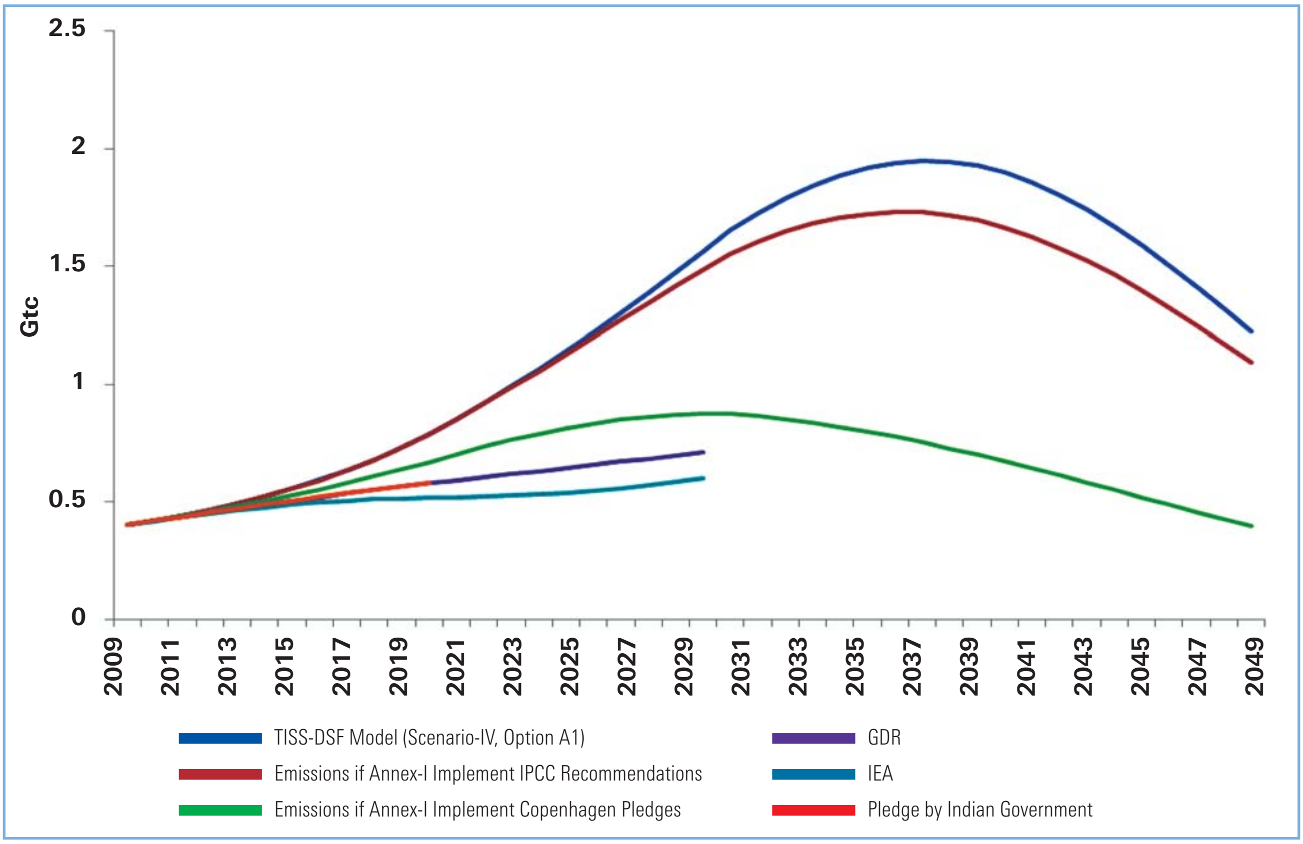



Figure 10

**Comparison of Proposals for The European Union**

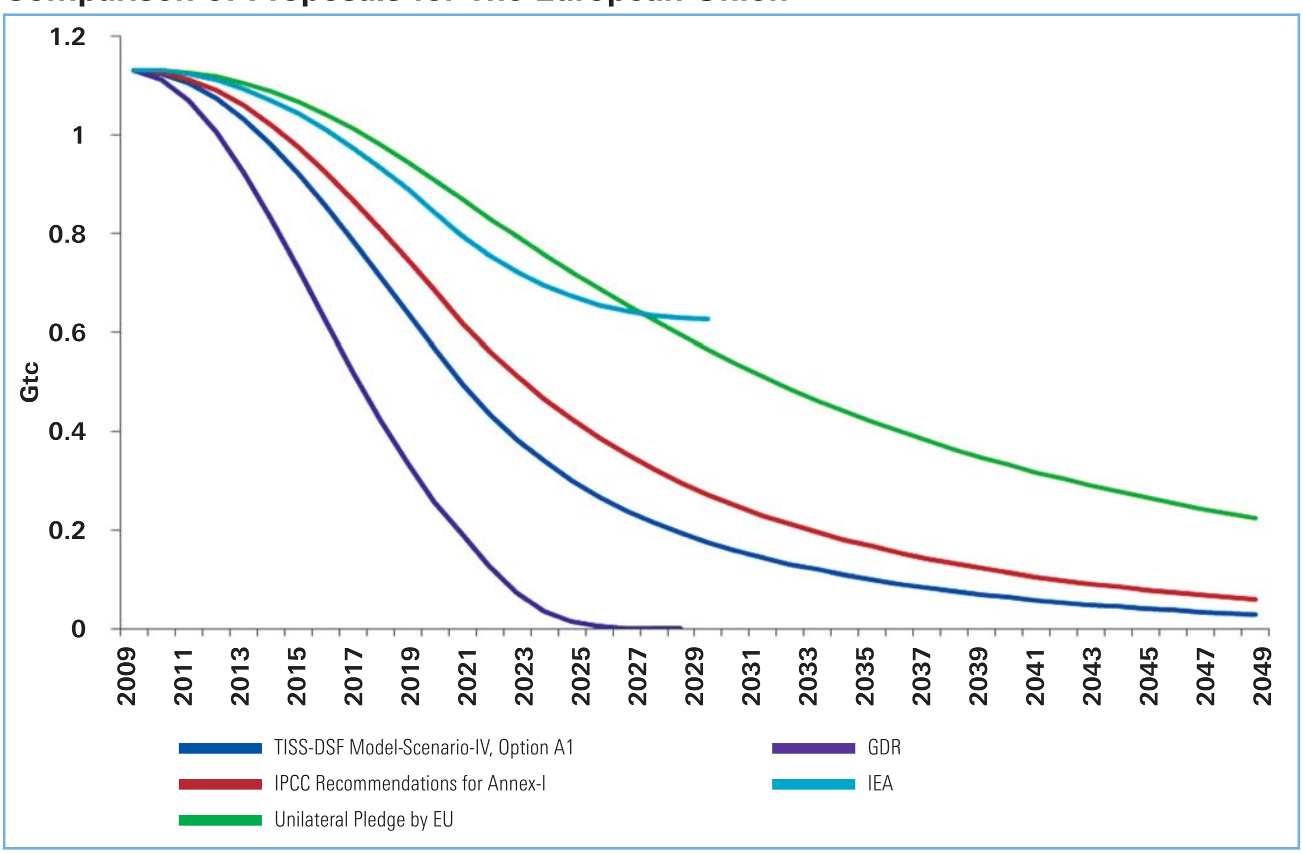
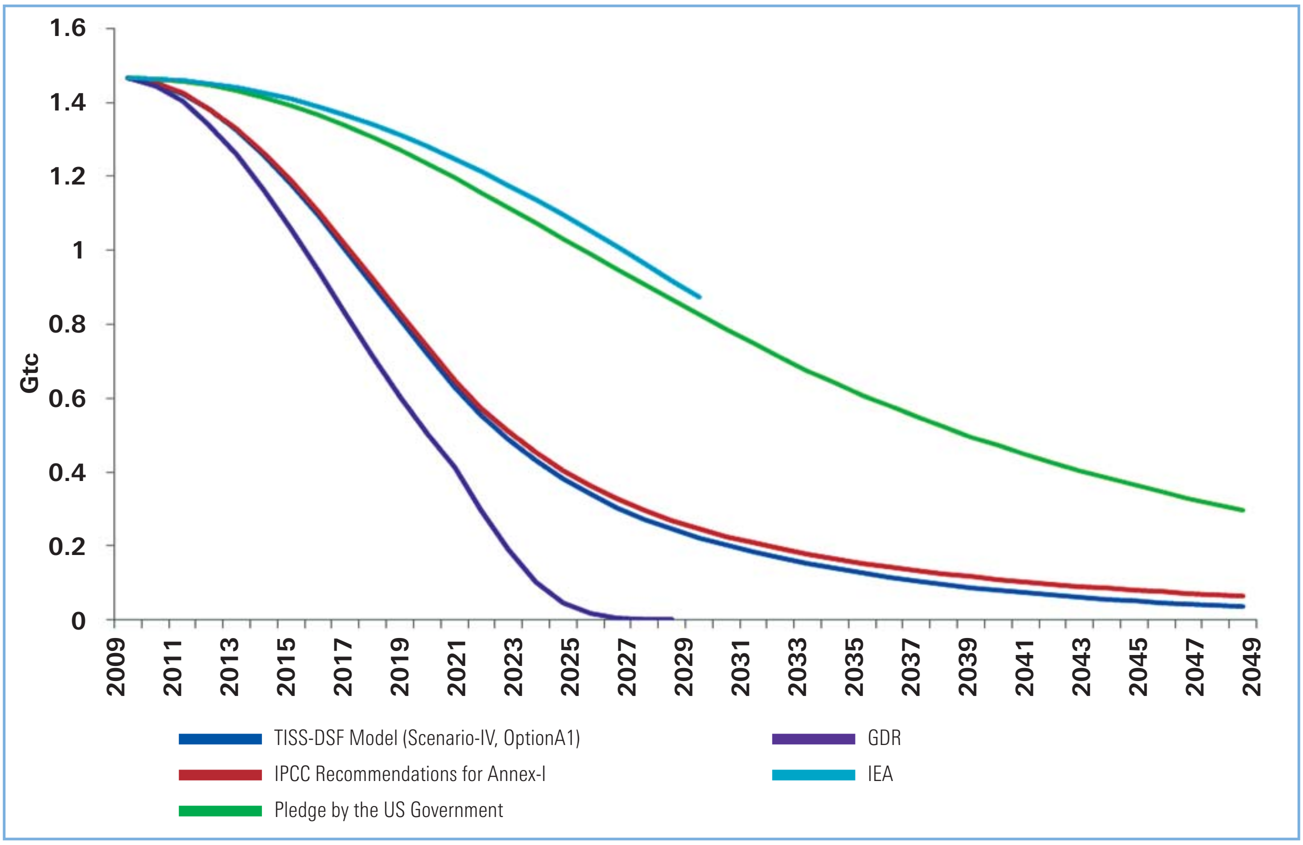


Figure 11

**Comparison of Proposals for USA**



# 7 Final Considerations

We may begin this discussion by pointing out that our ``dynamical'' emissions model actually serves three distinct purposes.

The first is that it may be treated purely as an emissions model. We have already demonstrated this by utilising the model to study four different scenarios, each of which has different sets of objectives. We may also add to this the fact that in the computations we may set the parameters referred to in Table 2 to different values. In such cases too we would generate different scenario.

We may even add other criteria to the model such as economic indicators including GDP per capita and so on.

The second use of the model is that it provides a class of base scenarios over which further considerations of burden-sharing in mitigation could be implemented. Most base scenarios that have been generated in the literature (and utilised in the work of the IPCC) have depended heavily on economic assumptions. We have already made the point that it is valuable to discuss burden-sharing in mitigation based on purely global environmental criteria in the first instance. From the economic point of view, this model makes no more than the minimal assumption that carbon space is a ``necessity.'' This is especially useful in policy-making where conservative assumptions regarding future technology seem more appropriate to defining baseline scenarios.

The third use of the model is to generate baseline scenarios that strongly reflect considerations of equity. This paper has focused strongly on this aspect of the model. Three further points may be noted in this connection. The first is that the equity criteria can be implemented across the board for all regions and countries in a uniform manner. The second is that the ``dynamical'' model provides a mechanism for differentiating between different developing nations through the same set of criteria as has been used for all countries. The third is that other scenarios for burden-sharing in mitigation action may be compared to the result of this equity-based model in order to provide quantitative estimates of the burden that will actually be borne by the developing countries. Such estimates in terms of the share of carbon budgets that accrues to each country appear to be more robust and invariant than considerations such as efficiency enhancements or deviations from business-as-usual. The last has always been criticized, in part justifiably, as a somewhat fuzzy notion that is open to several interpretations.

However it must be added that this model provides, in the final analysis, what are indicative strategies. While the model provides both a budget and an associated emission trajectory for various regions/countries it is clear that the former is a more robust parameter in terms of climate negotiations. It is obvious that for the same carbon budget nations may, depending on their national circumstances, choose quite different strategies for utilising the budget. Some, again depending on their national circumstances, may even choose to trade their allocation with other nations (especially those with ambitious reduction targets), though it would be untenable if all nations were uniformly required to trade specified fractions of their share of carbon space as part of a global climate deal. Thus emissions trajectories are quite open to modification based on political considerations or technological innovation.

From a climate justice perspective on global mitigation action, this model provides the following insights:

i) We establish yet again that the fate of energy development in developing nations is strongly dependent on the actions of the advanced industrial nations. The need to impose a carbon budget on the world as a whole leads to constraints on the development trajectories of developing nations. How serious these constraints will be clearly depend on the extent to which developed nations are prepared to stay within their carbon budget and are willing to work towards the necessary mitigation action. From this point of view the considerations in this paper provide an indication of the type of strategies that would lead to developing actions being able to access close to their fair share of carbon space.

ii) It is also evident from our considerations that the Emerging Economies have a considerable role to play in global mitigation action. Though it is conventional to include India in the ranks of the Emerging Economies, it is clear that this description does not fit India well and it would be more correct to include India in the ranks of the category that we refer to as RoTW.

iii) In a significant step, we have studied the consequences of replacing the base year for historical responsibility by 1970, compared to the much-used 1850. This is not without a price, particularly for some large developing countries (notably China), who will see their current utilisation of carbon space rise. However it may nevertheless be worth considering such a shift of base year, particularly because it enormously strengthens the case being made by the developing nations. This shift of base year as we have shown also allows us to provide a more equitable distribution of carbon space, particularly among the developing nations, since irrespective of the base year, the developed nations have to cut at the same deep and significant rates. This is undoubtedly a consequence of the over occupation of carbon space by the developed nations, but the brute fact that carbon dioxide already up in the atmosphere cannot be scrubbed out, forces the consideration of an equitable distribution of carbon space among developing nations on to the climate agenda. Even in terms of entitlements, the negative entitlement of the Annex-I countries at 2009 changes from -127 Gt of C to -100 Gt of C. It is arguable whether a shift from the former to the latter is a significant loss.

iv) Among the developing countries, India in particular needs to align its mitigation strategy keeping in mind the carbon budget realities. The carbon budget perspective shows that the promise of keeping India's per capita emissions below that of the developed nations at all times, is unnecessarily restrictive. Indeed the per capita strategy is likely to lead to a loss of carbon space, space that could be either utilised or traded, or made the basis of negotiations involving financial and technological transfers. However as we have noted India's claims for carbon space in our scenarios are still relatively modest. In our main scenario, the target in economic terms appears to be the current levels of per capita energy use in mid-range developed countries (at current levels of the emissions intensity of energy).

v) For all developing countries, carbon budgets represent a restriction but nevertheless one within which greater flexibility is available compared to approaches such as specifying reductions in milestone years, specifying reductions from business-as-usual growth or specifying peaking years.

Carbon budgets also allow significant flexibility for the large number of developing nations that are outside the ranks of the Emerging Economies. However such flexibility cannot be retained if a significant level of carbon trading is undertaken by these developing countries in the short and medium term.

# Acknowledgements

An earlier version of this paper was presented as the background paper to the meeting on ``Global Carbon Budgets and Equity in Climate Change'' held at TISS, Mumbai on June 28-29, 2010. We are grateful to the participants for their important and detailed critiques. The final form of the paper owes much to the discussions at this meeting.

An earlier version of this paper was presented at the CASS Forum (2010 Economics) on Climate Justice and the Carbon Budget Approach, Beijing, April 15-16, 2010

Other versions of this paper were also presented at the National Research Conference on Climate Change (Organised by IIT-Delhi, IIT-Madras and CSE), Delhi, March 5-6, 2010 and the International Conference on Climate Change and Developing Countries (CCDC-2010), Kottayam, Kerala, February 19-22, 2010

# Appendix-1

## Some Details of the Emissions Model

We work with a GAMS-based[7] emissions model that models emission trajectories for various countries and regions based on constraints that are specified by the user. The model optimizes (minimizes in our case) the deviations from these constraints.

Inputs:

As inputs we specify i) current emissions, ii) the current rate of growth of emissions, iii) the current total stock of carbon in the atmosphere and the percentage contribution of all countries/regions to this global stock and iv) the population, for 12 countries and 4 regions: USA, EU27, Russian Federation, Japan, Australia, Canada, Other Annex-I countries (the remaining Annex-I countries), China, India, South Africa, Brazil, Indonesia, Mexico, South Korea, Other Emerging Economies[8] and the Rest of the World.

We provide below more details regarding these inputs:

(I) Current emissions (2009) – The current (2009) flow of emissions for each country and region is a sum of the total emissions from the non-LUCF (Land Use Change and Forestry) sector as well as the LUCF sector. However, the data available for the LUCF sector is not as robust as the non-LUCF sector. We have included it nevertheless as proposals by many countries include this sector as a major area for mitigation of emissions. *The non-LUCF data has been taken from CAIT database 7.0. It is available till 2006 and has been extrapolated to 2009 using the growth rates that are calculated by taking the average growth rates for the last 5 years. LUCF data has been taken from CAIT database 6.0. It is available till 2000 and has been extrapolated to 2009.*

(II) Current rate of growth of emissions – This is the average of the rate of growth of total emissions (LUCF + non-LUCF) for the last 5 years for each country and region.

(III) The percentage contribution to total stock in the atmosphere – Historical data for annual flow of non-LUCF emissions is available for each country. However, similar data is not available for LUCF emissions. Therefore, input for the total stock at the starting year (current year) is calculated from the known addition of parts per million of carbon in the atmosphere since the industrial revolution ( 387.27 - 275 ppm = 112.27 ppm = 239.13 GtC GtC which is the net stock in the atmosphere after taking into consideration absorption by sinks such as the upper and lower ocean). The percentage contribution of each country to this stock is calculated based on their non-LUCF emissions as part of total global non-LUCF emissions. This is a reasonable assumption given the limitations imposed by the non-availability of reliable data on LUCF emissions as well as the fact that non-LUCF emissions form the most significant part of the annual flow of emissions – more than 85%.

(IV) Population – The model can be run on either constant population basis, i.e. all values of per capita emissions and share of total atmospheric carbon space are calculated based on the current population only, or on a moving population basis which includes projections done by the UN World Population Prospects for the population of each region from the current year up to 2050.

The model:

The mathematical problem we deal with here is one of constrained optimization. We take a budget approach to obtain the future emissions trajectory for each country and region. Depending on a political consensus, the world will have to contend with a range of probabilities for a temperature increase of agreed value. For example, for a mean probability of 75% of keeping temperature increases below 2 deg C, the total carbon budget available to the world for the period 2000-2050 is 1000 GtCO2 (273 GtC) and for a mean probability of 50% the total carbon budget available to the world for 2000-2050 is 1440 GtCO2

7 General Algebraic Modelling System or GAMS is a modelling system for mathematical programming and optimisation.

8 By ``Other Emerging Economies'' we refer here to Argentina, Chile, Egypt, Iran, Israel, Malaysia, Saudi Arabia, Singapore, Taiwan, Thailand, Uzbekistan and Venezuela.

(393 GtC). This global budget is the primary constraint in our problem.

Symbolically,

A = Global Budget – ∑(Cumulative emissions of each country and region)

The individual emission trajectories for each country and region will then decide their contribution to the sum of cumulative emissions.

Two constraints determine this trajectory for each region/country:

i) The difference between their *fair share* of the total atmospheric stock based on population and their *actual contribution* to the stock. Symbolically,

B = (Fair Share of Total Stock – Actual Share of Total Stock)$_{\text{for each country}}$

ii) The difference between an *acceptable threshold for annual per capita emissions and the actual annual per capita emissions* for each country. Symbolically,

C = (Acceptable per capita emissions – Actual per capita emissions)$_{\text{for each country}}$

The optimizer minimizes the negative deviations from the global budget, the negative deviations from the fair share of stock and negative deviations from the acceptable level of per capita emissions. Symoblically,

Objective Function = Minimize (Negative A + Negative B + Negative C)

These constraints determine whether the countries and regions will have to reduce their emissions or will be allowed to increase their emissions. Thus the degree of reduction or increase will depend upon how far the countries are from their fair share of stock and how far they are from acceptable levels of annual per capita emissions, both within the constraint of a global carbon budget.

In the model, the constraints for annual per capita emissions change as we go ahead in time, e.g. in the first time period (2009 to 2020) countries with per capita emissions higher than 7 tons of CO2/person are penalized and the others are not. In the second time period (2020 to 2040) this threshold changes to 4 tons of CO2/person. And beyond 2040 it is 2 tons of CO2/person.

To generate the actual trajectories of emissions we use a simple mathematical formula, wherein the changes in emissions in a year are calculated as a percentage of the emissions in the previous year. The time-line for the projections – 2009 to 2100 – is divided into 4 time periods: 2009 to 2020, 2020 to 2030, 2030 to 2050 and 2050 to 2100. For each of the milestone years, viz. 2020, 2030, 2050 and 2100 a maximum and minimum rate of change of annual emissions are specified (for 2009 there is already a known current rate of growth for each country). Based on the constraints mentioned above, i.e. the global budget, contribution to carbon stock and per capita emissions, the optimizer chooses a value in between the maximum and minimum rates of change that have been specified. So for example, if the optimizer chooses a decline rate of -8% in 2020 for the USA, it means that the rate of emissions reduction for the US in 2020 (with respect to 2019) should be -8%. If the current rate of emissions for the US is 1% then an interpolated value is calculated between the two points (+1% in 2009 and -8% in 2020) and is used as the annual rate of reduction in emissions, to obtain a trajectory for the US for the first time period. A similar exercise is done for the other time periods for all countries and regions. The maximum and minimum limits specified for the annual rates of change of emissions are the same for all countries within every time period. The optimizer will choose a number at the extremes or at an intermediate value in the range based on how far the constraints that are specified are violated by the country or region in question.

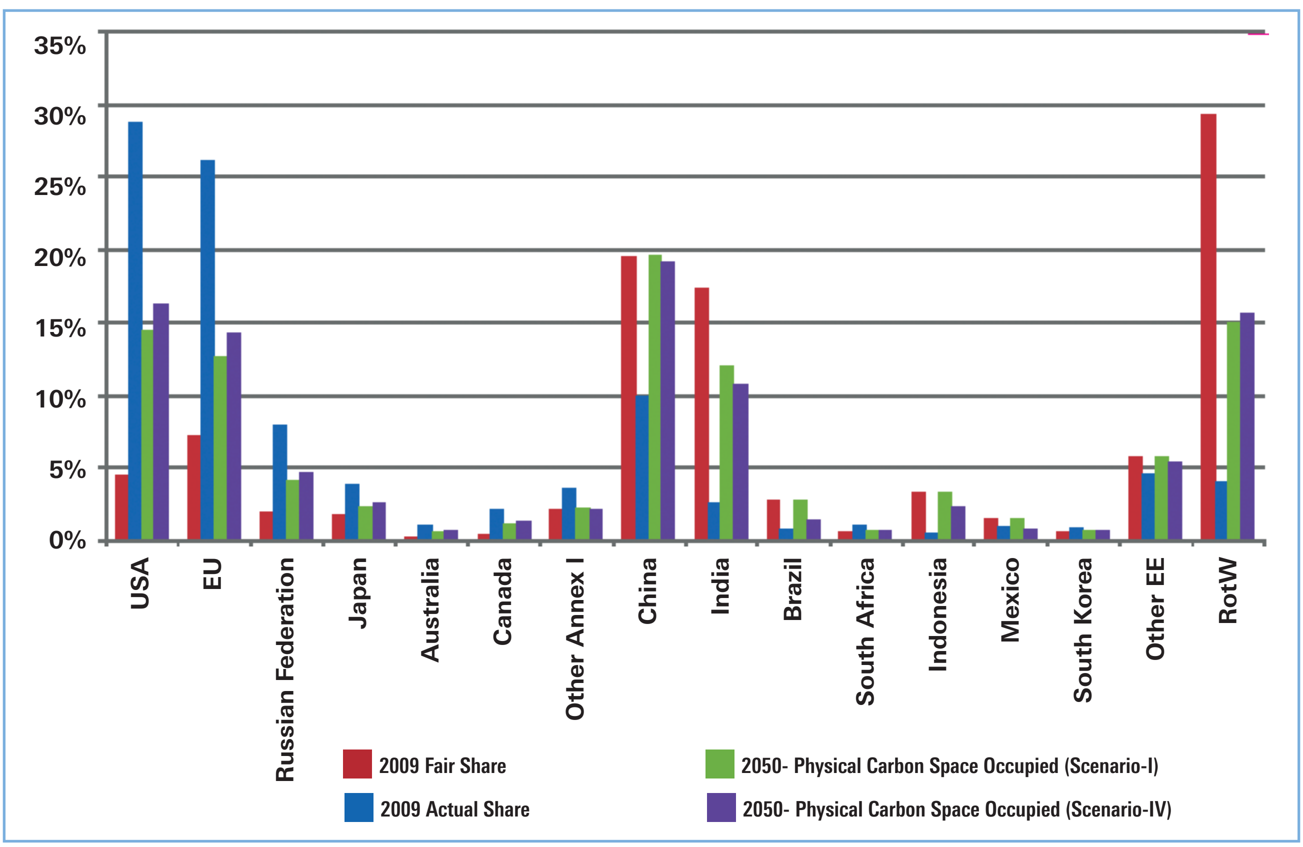
# Appendix-2

| Table I. Historical Responsibility with 1850, 1900 and 1970 as Base Years | | | | |
|---|---|---|---|---|
| | Non- LUCF Only | | | Fair Share |
| | 1850 Basis | 1900 Basis | 1970 Basis | 2009 Population Basis |
| USA | 28.8% | 28.9% | 24.4% | 4.6% |
| EU (27) | 26.1% | 24.7% | 19.9% | 7.2% |
| Russian Federation | 8.0% | 8.3% | 8.9% | 2.0% |
| Japan | 4.0% | 4.1% | 5.1% | 1.8% |
| Australia | 1.1% | 1.2% | 1.3% | 0.3% |
| Canada | 2.2% | 2.2% | 2.2% | 0.5% |
| Other AnnexI | 3.6% | 3.7% | 4.0% | 2.2% |
| China | 10.0% | 10.3% | 13.5% | 19.6% |
| India | 2.6% | 2.7% | 3.3% | 17.4% |
| Brazil | 0.9% | 0.9% | 1.1% | 2.8% |
| South Africa | 1.1% | 1.2% | 1.3% | 0.7% |
| Indonesia | 0.6% | 0.7% | 0.8% | 3.3% |
| Mexico | 1.1% | 1.1% | 1.4% | 1.6% |
| South Korea | 0.9% | 1.0% | 1.3% | 0.7% |
| Other Emerging Economies | 4.7% | 4.8% | 6.1% | 5.9% |
| Rest of the World | 4.2% | 4.3% | 5.4% | 29.3% |

| Table II. Current Entitlements | | | | | |
|---|---|---|---|---|---|
| | Historical Conttribution (%) | Fair Share (%) | Total Fair Share (GtC) | Current Contribution to Stock | Current Entitlements |
| | 1850-2009 | 2009 Population Basis | 1850-2050 (2009 Population Basis) | 1850-2009 | 2009 |
| USA | 28.8% | 4.57% | 28.91 | 95.71 | -66.79 |
| EU (27) | 26.1% | 7.21% | 45.59 | 86.74 | -41.15 |
| Russian Federation | 8.0% | 2.05% | 12.95 | 26.72 | -13.77 |
| Japan | 4.0% | 1.85% | 11.68 | 13.17 | -1.49 |
| Australia | 1.1% | 0.31% | 1.96 | 3.81 | -1.85 |
| Canada | 2.2% | 0.49% | 3.09 | 7.31 | -4.22 |
| Other AnnexI | 3.6% | 2.19% | 13.81 | 11.89 | 1.92 |
| China | 10.0% | 19.57% | 123.69 | 33.09 | 90.60 |
| India | 2.6% | 17.40% | 110.00 | 8.66 | 101.33 |
| Brazil | 0.9% | 2.81% | 17.78 | 2.88 | 14.91 |
| South Africa | 1.1% | 0.73% | 4.60 | 3.79 | 0.80 |
| Indonesia | 0.6% | 3.34% | 21.12 | 2.10 | 19.02 |
| Mexico | 1.1% | 1.59% | 10.07 | 3.59 | 6.48 |
| South Korea | 0.9% | 0.70% | 4.44 | 3.12 | 1.32 |
| Other Emerging Economies | 4.7% | 5.86% | 37.04 | 15.55 | 21.49 |
| Rest of the World | 4.2% | 29.31% | 185.27 | 13.88 | 171.39 |

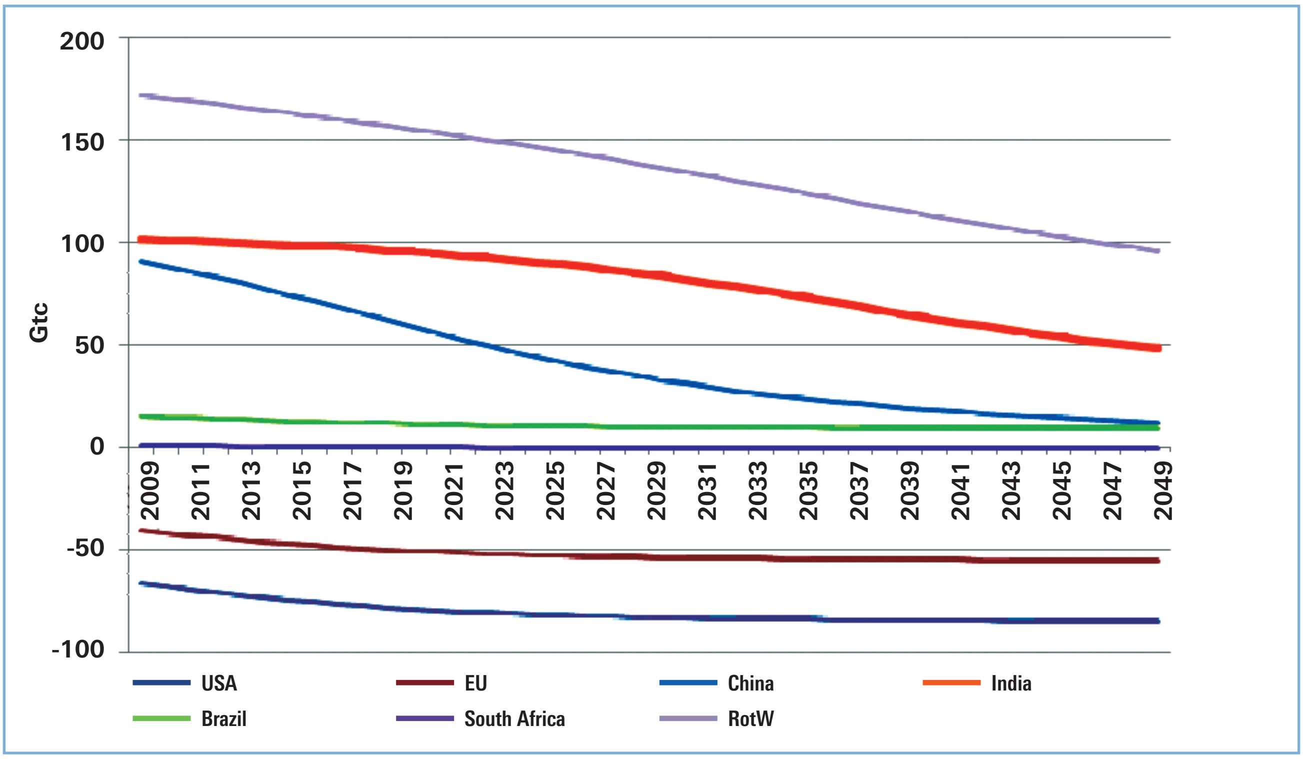
Figure(i)

**2009 Fair and Actual Shares of Emissions Stock**

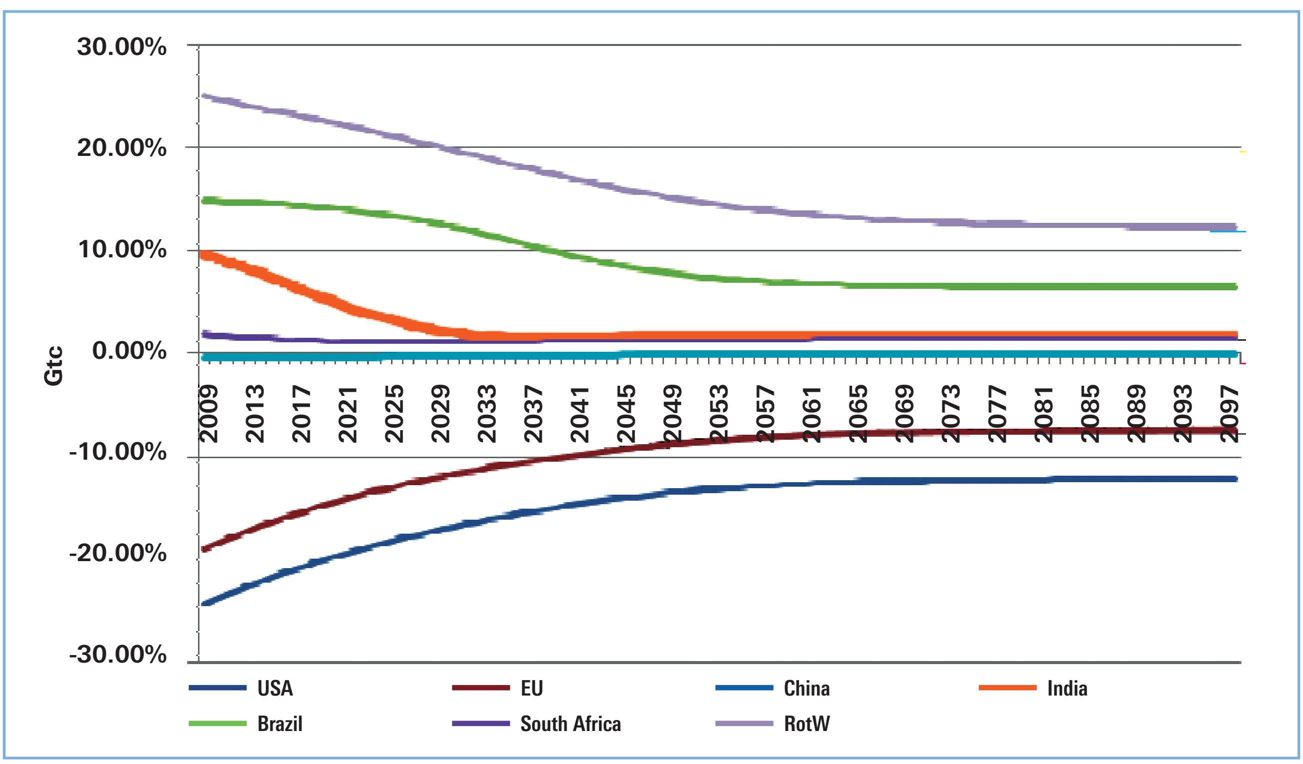


Figure(ii) Future Entitlements

**Absolute Entitlement for each Country/Region from 2009 to 2050 (1850 Basis - Option A)**




Figure(iii)
**Fair Share – Actual Contribution to Stock (% Basis)**



| Table III. Difference Between Physical Carbon Space based on Constant Population and Moving Population | | |
|---|---|---|
| | **Constant Population** | **Moving Population** |
| USA | 18.41 | 18.41 |
| EU (27) | 14.38 | 14.38 |
| Russian Federation | 6.08 | 6.08 |
| Japan | 4.42 | 4.42 |
| Australia | 1.61 | 1.61 |
| Canada | 2.14 | 2.14 |
| Other AnnexI | 3.14 | 3.14 |
| China | 79.08 | 57.96 |
| India | 53.43 | 59.27 |
| Brazil | 5.86 | 8.32 |
| South Africa | 1.53 | 1.53 |
| Indonesia | 10.45 | 12.44 |
| Mexico | 2.08 | 2.08 |
| South Korea | 1.87 | 1.87 |
| Other Emerging Economies | 17.91 | 20.98 |
| Rest of the World | 75.81 | 79.88 |
| **Total** | **298.20** | **294.52** |

| Table IV. Current and Future Entitlements – 1850 Basis | | | | | |
|---|---|---|---|---|---|
| **1850 Basis - Constant Population** | **Total Entitlements (GtC)** | **Actual Current Occupation** | **Future Entitlements** | **TISS-DSF-Scenario-A* Allocations** | **TISS-DSF-Scenario-A* Allocations** |
| | **1850-2050** | **2009** | **2010-2050** | **2010-2050 (Based on 48% cuts (of 1990 levels) by 2020 and 97% cuts by 2050 by Annex-I)** | **2010-2050 (Based on 63% cuts (of 1990 levels) by 2020 and 99% cuts by 2050 by Annex-I)** |
| USA | 28.90 | 95.71 | -66.81 | 18.41 | 14.54 |
| EU | 45.57 | 86.74 | -41.17 | 14.38 | 11.35 |
| Other Annex-I | 43.47 | 62.90 | -19.43 | 17.39 | 13.71 |
| India | 109.95 | 8.66 | 101.29 | 45.05 | 56.30 |
| China | 123.64 | 33.09 | 90.55 | 90.03 | 88.34 |
| Brazil | 17.78 | 2.88 | 14.90 | 5.40 | 5.74 |
| South Africa | 4.59 | 3.79 | 0.80 | 1.53 | 1.20 |
| Other Emerging Economies | 72.64 | 24.35 | 48.28 | 31.83 | 30.46 |
| Rest of the World | 185.19 | 13.88 | 171.31 | 76.37 | 75.79 |

| Table V. Current and Future Entitlements – 1970 Basis | | | | | |
|---|---|---|---|---|---|
| **1970 Basis - Constant Population** | **Total Entitlements (GtC)** | **Actual Current Occupation** | **Future Entitlements** | **TISS-DSF-Scenario-A* Allocations** | **TISS-DSF-Scenario-A* Allocations** |
| | **1850-2050** | **2009** | **2010-2050** | **2010-2050 (Based on 48% cuts (of 1990 levels) by 2020 and 97% cuts by 2050 by Annex-I)** | **2010-2050 (Based on 63% cuts (of 1990 levels) by 2020 and 99% cuts by 2050 by Annex-I)** |
| USA | 28.90 | 80.97 | -52.07 | 18.41 | 14.54 |
| EU | 45.57 | 66.07 | -20.51 | 14.38 | 11.35 |
| Other Annex-I | 43.47 | 71.32 | -27.85 | 17.39 | 13.71 |
| India | 109.95 | 10.83 | 99.12 | 58.39 | 60.53 |
| China | 123.64 | 44.72 | 78.92 | 71.87 | 71.39 |
| Brazil | 17.78 | 3.72 | 14.06 | 8.07 | 11.29 |
| South Africa | 4.59 | 4.16 | 0.43 | 1.53 | 1.20 |
| Other Emerging Economies | 72.64 | 32.20 | 40.44 | 29.85 | 32.31 |
| Rest of the World | 185.19 | 18.01 | 167.18 | 76.15 | 79.24 |
| **Total** | **631.73** | **332.00** | **299.73** | **296.05** | **295.57** |

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# Agenda for conference on 'Global Carbon Budgets and Equity in Climate Change',

## Tata Institute of Social Sciences, Mumbai, June 28-29, 2010

| Day 1: Monday, June 28, 2010 | | |
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| **Registration** | | 8:30 onwards |
| Inaugural Session | T. Jayaraman<br>Chair – S. Parasuraman (Director, TISS)<br>Inaugural Speech – Shri. Jairam Ramesh, Honorable Minister, MoEF<br>Martin Khor | 9:00 – 9:45 |
| **Tea Break** | | 9:45 – 10:00 |
| Session I: **An Indian Carbon Budget Approach** | Chair – Suzana Ribeiro<br>Introducing the model and the basics – Tejal Kanitkar<br>Global carbon budgets and burden sharing regimes – T Jayaraman<br>Discussants – Prodipto Ghosh, Benito Muller<br>Chair Remarks & Discussion | 10:00 – 11:30 |
| **Break** | | 11:30 – 11:45 |
| Session II: **Carbon Budgets – A Paradigm and its Implications** | Chair – Abhijhit Sen<br>Carbon Space as Development Space – Prabir Purkayastha<br>Carbon Space and the Shared Vision – Mukul Sanwal<br>Equity and Energy Access in Developing Countries – Surya Sethi<br>Discussants – R. Ramachandran, Kirit Parikh<br>Chair Remarks & Discussion<br>(Session will spill-over to post-lunch if needed) | 11:45 – 13:15 |
| **Lunch** | | 13:15 – 14:15 |
| Session III: **More Carbon Budgets** | Chair – Prodipto Ghosh<br>Carbon budgets & Developing Countries – Martin Khor<br>Global Carbon Space and Development: Possible Pathways - Suzana Ribeiro<br>Carbon Space Rents – Kirit Parikh<br>Discussants – T. Jayaraman, Daniel Klingenfeld<br>Chair Remarks & Discussion | 14:15– 16:15 |

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| **Tea Break** | | 16:15 – 16:30 |
| Further Discussion Session | Chair – R. R. Rashmi, Jt. Secy., MoEF.<br><br>Girish Sant, Raman Mehta, Meena Raman, D. Raghunandan and others.<br><br>(Can be extended if necessary). | 16:30 – 17.30 |
| **Conference dinner** | | 19:30 |

| **Day 2: Tuesday, June 29, 2010** | | |
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| Session IV: **Other Budget and Equity based Approaches** | Chair – Mukul Sanwal<br><br>The German Budget Proposal – Daniel Klingenfeld (PIK-WBGU)<br><br>The GDR Framework – Sanjay Vashist (HBF)<br><br>Comparative Analysis on Equity - Shirish Sinha (WWF)<br><br>Chair Remarks & Discussion | 9:30 – 11:30 |
| Tea Break | | 11:30 – 11:45 |
| Session V: **International Climate Regime and the Budget viewpoint** | Chair – Pranay Verma, Dir. (CC), MEA<br>Meena Raman, Navroz Dubash, Raman Mehta, D. RaghunandanChair's Remarks and Discussion | 11:45 – 13:00 |
| **Lunch** | | 13:00 – 14:00 |
| Session VI: **Taking Carbon Budgets Forward**<br><br>Prospects, Issues, Knowledge gaps, Implications for Negotiations, Possible national and international collaborations/initiatives on budgets | Chair – J. M. Mauskar, Addnl. Secy.,MoeF<br><br>Martin Khor,, Suzana Ribeiro, Mukul Sanwal, D. Raghunandan, Surya Sethi and others. | 14:00 – 15:30 |

# Participants List for conference on 'Global Carbon Budgets and Equity in Climate Change',

## Tata Institute of Social Sciences, Mumbai, June 28-29, 2010

### Government

1. Shri. Jairam Ramesh, Honourable Minister of State (Independent Charge), Environment & Forests, Government of India
2. Shri. J.M. Mauskar, Additional Secretary, Ministry of Environment & Forests, Government of India
3. Shri. R. R. Rashmi, Joint Secretary, Ministry of Environment & Forests, Government of India
4. Shri. Varad Pande, OSD to the Minister, Ministry of Environment & Forests, Government of India
5. Shri. Pranay Verma, Director (Climate Change), Ministry of External Affairs, Government of India

### International Participants

1. Martin Khor, Executive Director, South Centre, Geneva
2. Suzana Kahn Ribeiro, Federal University of Technology, Rio de Janeiro, Brazil
3. Meena Raman, Third World Network, Geneva
4. Benito Müller, Oxford Institute for Energy Studies, Oxford
5. Daniel Klingenfeld, Potsdam Institute for Climate Impact Research and German Advisory Council on Global Change, Potsdam, Germany

### National Participants

1. Abhijit Sen, Member, Planning Commission, Government of India
2. Mukul Sanwal, Former Policy Advisor, UNFCCC
3. Prodipto Ghosh, TERI and Former Climate Change Negotiator for India
4. Kirit Parikh, Former Member, Planning Commission, Government of India
5. Surya Sethi, Former Climate Change Negotiator for India
6. Shirish Sinha, WWF India, New Delhi
7. Tirthankar Mandal, WWF India, New Delhi
8. Girish Sant, Member, Low-Carbon Committee and PRAYAS, Pune
9. Daljit Singh, PRAYAS
10. Ashwin Gambhir, PRAYAS
11. Soumyabrata Mukherjee, PRAYAS

12. Navroz Dubash, Member, Low-Carbon committee and Centre for Policy Research, New Delhi
13. R. Ramachandran, Member, PM's National Panel on Climate change and Science Correspondent, Frontline
14. Praful Bidwai, Commentator on policy issues and Journalist
15. Prabir Purkayastha, Delhi Science Forum, New Delhi.
16. D. Raghunandan, Member, Low-Carbon Committee, and Delhi Science Forum
17. Raman Mehta, ActionAid India, New Delhi
18. Harjeet Singh, ActionAid India, New Delhi
19. Benny Kuruvilla, Focus on the Global South, New Delhi
20. Walter Mendoza, Ethics in Climate Change Network and Centre for Education and Documentation, Mumbai
21. Sanjay Vashisht, Climate Action Network – South Asia
22. K Sirinivas, Greenpeace, New Delhi
23. Siddharth Pathak, Greenpeace, New Delhi
24. Vanita Suneja, Oxfam India, New Delhi
25. Manish Kumar Shrivastava, TERI, New Delhi.
26. Kunal Sharma, Shakti Foundation, New Delhi.
27. Ronald Abraham, New Delhi
28. B. Siddarthan, DFID, New Delhi
29. Naman Gupta, DFID
30. T. Jayaraman, Chairperson, Centre for Science, Technology and Society, School of Habitat Studies, TISS
31. Tejal Kanitkar, Centre for Science, Technology and Society, School of Habitat Studies, TISS
32. Mario D'Souza, Centre for Science, Technology and Society, School of Habitat Studies, TISS

## For further details, please contact:

**Center for Science Technology and Society**
**Tata Institute of Social Sciences**
Deonar, Mumbai 400088
Tel: 022-2552 5372
Email: tjayaraman@tiss.edu