A Climate Agreement beyond 2012

GAUTAM DUTT

As the first commitment period of the Kyoto Protocol comes to a close in 2012, the world faces another decision point at the United Nations Framework Convention on Climate Change meeting in Copenhagen in December. It is clear that total world emissions of greenhouse gases need to decrease sometime during the coming decade, and fall sharply thereafter, if we are to avoid disastrous and irreversible climate change. While industrialised countries generally emit much more per capita than developing countries, some of the latter have per capita emissions approaching the world average. This paper proposes that these advanced developing countries take on commitments to limit future emissions increase to improvements in the gross domestic product or, better yet, the Human Development Index, noting that some countries have achieved much more emission-efficient development than others. Recognising differences in the accuracy of greenhouse gas emissions accounting, we propose separate treatment for energy-related CO_2 emissions, forestry, agriculture, and fluorinated gases.

Gautam Dutt (*gdutt@mgminnova.com*) is with MGM Innova, a company involved in developing climate change mitigation projects.

The Kyoto Protocol commits industrialised countries that ratified the Protocol to reduce their total emissions of greenhouse gases (GHGs) in the period 2008-12 by about 5% compared to their emissions in 1990. No commitments were made beyond 2012. Developing countries did not make any quantitative commitments on their GHG emissions.

In recent years, there have been considerable discussions on possible agreements going beyond 2012. Two years ago, we reviewed some of these (Dutt and Gaioli 2007). One key development since then is that, following the 2008 US presidential elections, the US has taken a stronger position in reducing GHG emissions. A bill passed in 2009 in the House of Representatives sets down a policy framework for achieving drastic emissions reductions (HR 2998 (2009)).

Before looking beyond 2012, let us first review progress to date. Figure 1 (p 40) shows GHG emissions in industrialised countries from 1990 to 2006. Overall, their emissions decreased by 4.7% over this period. If we exclude the countries of the former Soviet Union and eastern Europe (so-called economies in transition, EIT), emissions in the remaining industrialised countries went up by about 10% over this period. This is considerably below their increase in gross domestic product (GDP). Considering only carbon dioxide (CO_2) emissions in the developed countries, the emissions intensity (tonnes of CO_2 per 2005 US$) decreased from 757 in 1990 to 566 in 2004, a decrease of about 25% (WRI 2009).

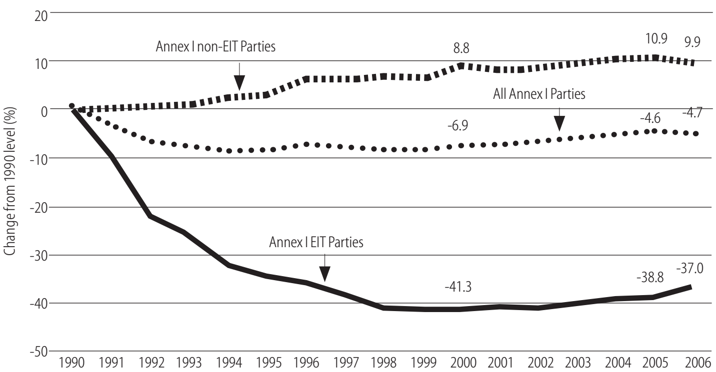
Figure 1 shows emissions without considering the effects of land use, land use change and forestry (LULUCF). The latter emissions estimates are much less reliable, and total GHG emissions including them published by the United Nations Framework Convention on Climate Change (UNFCCC) Conference indicate about the same overall effect for the sum of all industrialised countries (5.5% decrease from 1990 to 2006) and excluding EIT (9.1% increase) (http://unfccc.int/files/inc/graphics/image/gif/trends_including_ 2008.gif).

Let us next look at emissions by the US (included among industrialised countries in Figure 1) since it did not ratify the Kyoto Protocol. The data behind Figure 2 (p 40) indicate that total GHG emissions went up from 6,242 Tg CO_2-eq in 1990 to 7,262 Tg CO_2-eq in 2005, a 16% increase. Emissions per capita remained roughly unchanged over this period, while GHG emissions per unit of GDP decreased by about 25% (Figure 3, p 41). Thus, a country that was publicly making no commitments to mitigate climate change, also managed to reduce its emissions intensity by 25%.

Emissions from Developing Countries

As industrialised countries consider commitments to reduce GHG emissions for future years, they are also proposing that developing countries take on commitments. One of their arguments is that China is now the largest emitter of carbon dioxide, the main GHG. In our 2007 paper we emphasised the position that what matters are "per capita" emissions. Dividing the world into smaller countries would make each a smaller emitter, but would not change total emissions.

Figure 1: Total Emissions of Greenhouse Gases from Industrialised Countries (Annex 1 Countries), 1990 to 2006
Greenhouse Gas Emissions Excluding LULUCF



1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
0	-10.2	-21.6	-25.8	-32.2	-34.4	-35.8	-38.5	-40.8	-41.2	-41.3	-40.8	-40.9	-39.4	-39.0	-38.8	-37.0
0	-0.1	0.3	1.0	2.3	3.3	6.2	6.3	6.6	6.7	8.8	8.1	8.7	9.9	10.7	10.9	9.9
0	-3.2	-6.6	-7.4	-8.4	-8.4	-6.9	-7.7	-8.2	-8.3	-6.9	-7.2	-6.8	-5.5	-4.9	-4.6	-4.7

Separate figures are shown for so-called economies in transition (former communist countries: former Soviet Union and eastern Europe) which are included among Annex 1. The term "excluding LULUCF" means that emissions from land use, land use change and forestry" have not been included in these data.
Source: http://unfccc.int/files/inc/graphics/image/gif/trends_excluding_2008.gif

As Raghunandan et al (2009) have pointed out, while industrialised countries are responsible for 75% of the historical GHG emissions, and therefore the current concentrations of GHG in the atmosphere, developing countries are now responsible for over 50% of emissions now being added to the atmosphere. The responsibility (total historical emissions) is shifting towards developing countries as the years go by. Thus, developing countries need to take a more explicit role in limiting GHG emissions, and not leave it exclusively as a responsibility of the industrialised countries.

One argument used by developing countries is that in order to develop, they would need necessarily to emit more GHGs. Let us analyse this assertion. The late A K N Reddy had described the "standard" paradigm on energy planning as follows (e g, Reddy, nd):

> According to this paradigm, development is equated with economic growth which is measured by the magnitude of the gross domestic product (GDP). Then, the paradigm argues that the only way we can increase growth is by pumping more energy into the economy. So, we are asked to think in terms of energy consumption as a necessary condition for economic growth. Thus, the paradigm says that if we want development, then we have to have economic growth, and if we want to increase GDP, we must increase energy consumption!

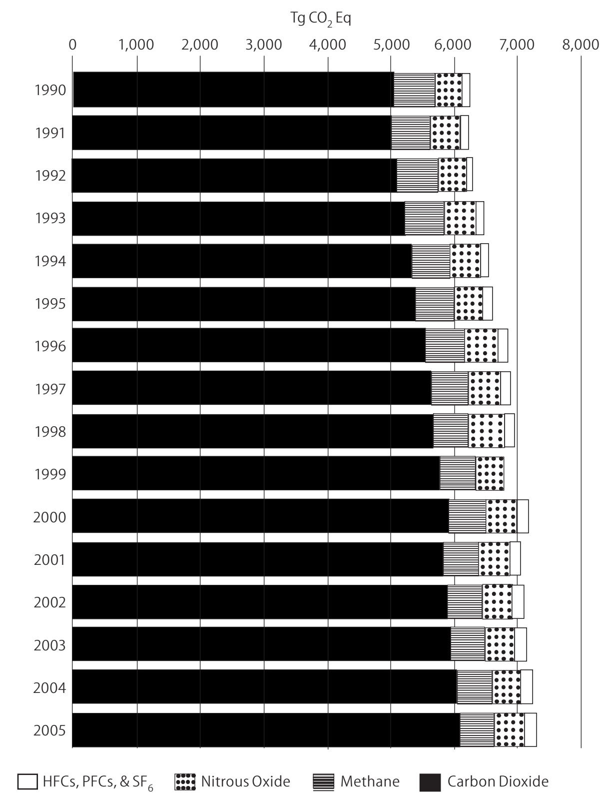
It is a simple extension of this paradigm to claim that more energy use means more GHG emissions. The standard paradigm on energy planning does not consider energy efficiency, while its extension to climate change also does not recognise renewable energy, other sources of carbon dioxide emissions, as well as GHGs other than carbon dioxide.

The standard paradigm on energy has been amply refuted and replaced by the sustainable-development paradigm (see, e g, Goldemberg et al 1988) and indeed has led to the widespread use of such indices as "energy consumption per unit GDP", as well as showing how this index has decreased steadily in virtually all industrialised countries since around 1980. We have already commented on a similar index "GHG emissions per unit GDP" and shown that this has also decreased in industrialised countries (Figure 1 and Figure 3).

Though we generally do not have time series of data on emissions from developing countries, there is evidence to suggest that the emissions intensity in developing countries has also decreased since 1990. For instance, new power plants in India emit only about 60% as much CO_2/kwh as the average power plant in use: the so-called Build Margin emissions factor (EF) for 2007-08 was 0.63 tCO_2/MWh, while the Operating Margin EF was 1.01 tCO_2/MWh (CEA 2008). Five different groups have recently modelled India's future emissions and project that emissions intensity would decrease considerably even without any additional new policies to mitigate climate change (GOI 2009). Furthermore, if we consider that GDP does not fully reflect development, the following examples show how development can be furthered while reducing emissions.

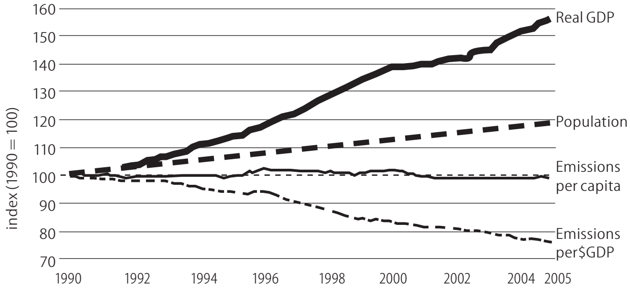
Over 1.6 billion people in the world lack access to electricity; roughly 25% are in India alone (TERI 2009). A kerosene wick lamp consumes 0.032 kg of fuel per hour (Dutt 1994). Operated

Figure 2: US Greenhouse Emissions by Gas, 1990-2005



Tg (teragramme) is the same as million tonnes. Thus the US emitted somewhat over 7 billion tonnes (or gigatonnes) CO_2-equivalent.
Source: United States Environmental Protection Agency (USEPA 2009).

Figure 3: Trends in US Greenhouse Gas Emissions Compared to Trends in Population and GDP (Per Capita and Per $GDP)



Sources: USEPA (2009).
BEA (2006), US Census Bureau (2005), and emission estimates in this report.

four hours a day, annual fuel consumption would be 46.7 kg/year, with CO_2 emissions of about 146 kg (assuming 3.1 kg CO_2 per kg of kerosene). One way of providing electricity in rural areas is through a solar lantern. Each lantern comprises a high efficiency electric lamp (fluorescent or LED) operated by a battery that is recharged using solar energy through a solar cell. Each solar lantern would therefore reduce CO_2 emissions by 146 kg per year. Since these electric lamps are vastly more efficient than kerosene lamps, even if they were powered by grid connected power plants, there would be considerable reduction in CO_2 emissions. For instance an 11 watt compact fluorescent lamp (CFL) operating four hours a day would consume 44 wh/day or 16.1 kwh/year. Assuming technical transmission and distribution losses of 15%, this would require electricity generation of 18.9 kwh/year. The average emission factor for the average Indian power grid is about 0.8 tCO_2/MWh (CEA 2008), so that generating 18.9 kwh at the average power plant would cause emissions of 15 kg CO_2/year. Thus, CO_2 emissions reduction of rural electrification would be about 146 kg/year for each solar lantern and 141 kg/year with electricity supplied by the Indian power grid. The 11 W CFL would provide over 10 times the amount of light (measured in lumens) than a kerosene wick lamp. Thus there would be considerable improvement in the quality of light and life through electric lighting, while the rural poor help mitigate climate change.

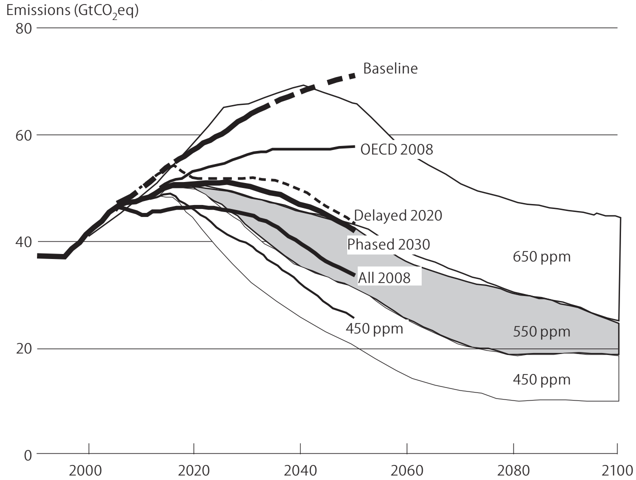
While rural lighting is an exceptional example of how furthering development also reduces emissions, it is not the only one. Improved cookstoves in developing countries can save fuel, be it based on fossil fuels, wood or other biomass fuels. Clean cooking alternatives consider better fuels (to replace traditional biomass fuels) as well as higher efficiency stoves, and provide considerable benefits in terms of reduced air pollution to the 2.6 billion people that depend on biomass fuels and coal (Goldemberg et al 2004). Even if all these people shifted to using a fossil fuel stove, such as LPG, the consumption of LPG estimated at 35 kg LPG/capita/year represents less than 1% global fossil fuel consumption (IEI 2008). Again there are renewable high-quality cooking fuel alternatives, e g, biogas, ethanol, and dimethyl ether; this last can be used in stoves very similar to LPG stoves. As long as their production is renewable, there would be no net CO_2 emissions in their use as a cooking fuel. Besides air pollution and CO_2 emissions from cooking using non-renewable biomass, there are products of incomplete combustion from cooking with solid fuels in traditional stoves which also make a significant contribution to global warming (as well as air pollution!). Besides GHGs, cooking also contributes to global warming in another way. Soot emitted by these stoves is deposited on snow and ice, which then absorb solar radiation much more, and hasten their melting. The main source of this so-called black carbon is cooking fires (Biello 2007; Ramanathan and Carmichael 2008). Incidentally, improved biomass stoves can also help reduce the climate impact of cooking with traditional biomass fuels (MacCarty et al 2008). Where animal dung cake is the cooking fuel used, e g, in places where wood resources are already depleted, the biogas route provides a clean cooking fuel and an organic fertiliser, while reducing GHG emissions.

The above two examples indicate how furthering development of the poor can actually help mitigate climate change. Of course, the world's poor are only responsible for a tiny amount of overall GHG emissions, and we need to look for most mitigation options elsewhere.

Mitigation Measures

Enkvist et al (2007) studied the cost and potential of a wide range of mitigation measures worldwide. They found that GHG emissions could be reduced by about six gigatonnes CO_2-eq per year worldwide by 2030 through measures with negative mitigation cost. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) also recognises the presence of a large mitigation potential at negative cost (Barker et al 2007). This is also the case in a more recent study, limited to industrialised countries, the "Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS)" study, conducted by the International Institute for Applied Systems Analysis (IIASA 2009). These are

Figure 4: Global GHG Emission Pathways: Baseline and Mitigation Paths to 2050, Compared to Stabilisation Pathways to 2100



OECD 2008 = all OECD countries apply a GHG tax of $ 25 per tonne of CO_2-eq; Delayed 2020 = all countries apply the tax, starting only in 2020; Phased 2030 = OECD countries apply the tax in 2008, BRIC in 2020 and Rest of the World (ROW) in 2030; All 2008 = all countries apply the tax, starting in 2008; 450 ppm = scenario to stabilise GHG concentrations in the atmosphere at 450 ppm CO_2-eq; For all $ 25 tax cases, the tax is escalating by about 2% per year after the initial year of introduction.
In this paper, the scenarios shown in the figure are considered here as possible pathways for future evolution of emissions, without regard to the policy recommendations implied in the OECD study.
Source: OECD (2008).

mostly energy efficiency measures that pay for themselves through energy cost savings alone, so that the cost attributable to climate change mitigation is negative. By way of comparison, Enqvist et al (2007) noted that a reduction of 18 GT CO_2-eq/year would be needed to stabilise atmospheric CO_2 concentration at 550 ppm and 26 GT CO_2-eq/year to stabilise at 450 ppm, in each case by 2030. Thus, zero or negative cost measures can make a significant contribution to mitigating climate change.

The existence of a large and cost-effective potential for energy efficiency improvement (and thereby negative cost climate change mitigation) has been known by all in the energy efficiency community. They point to the existence of barriers that prevent the potential to be fully realised (see, e g, Reddy 1991). One way of expressing this barrier is that the implied discount rates for investment decisions in energy efficiency are often much higher than rational discount rates. A wide range of programmes have been developed and implemented across the world to overcome these barriers, and while a great deal of success has been achieved, the remaining potential is still large.

The experience of the energy efficiency community is also relevant to the debate on policies to mitigate climate change. Imposing a so-called "carbon tax" or a tax based on the carbon content of fuels would increase the potential for energy efficiency (as well as switching to renewable fuels). However, despite the increase in this potential, we cannot simply assume that this potential will be attained without additional policies and measures to overcome barriers.

Before going forward on future commitments by industrialised and developing countries, let us first look at what the world as a whole needs to do to stabilise the climate. According to a recent study, in order to stabilise atmospheric CO_2 concentration at 450 ppm, total emissions must start to decline by about 2015, while to stabilise at 550 ppm, the reduction needs to start around 2020 (Figure 4, p 41). This calls for global reduction in emissions to start even sooner than what we had suggested earlier (Dutt and Gaoili 2007, Figure 5), based on the Contraction and Convergence model (GCI 2007). This change is most likely because emissions have grown more in recent years than that assumed in the earlier modelling.

If we consider the "phased 2030" scenario in Figure 4, as being an upper limit on world GHG emissions in order to stabilise CO_2 concentrations at a rather high 600 ppm, and compare it with population projections, world per capita emissions would need to go down substantially, as shown in Table 1. Note that India's per capita emissions in 1994, as reported in its National Communication to the UNFCCC, were 1.3 tCO_2-eq/year (GOI 2004), about five times lower than world average of about 6.9 tCO_2-eq *2000* (Table 1).

Table 1: Projections of Population, Maximum Allowable Total and Per Capita GHG Emissions, up to 2050

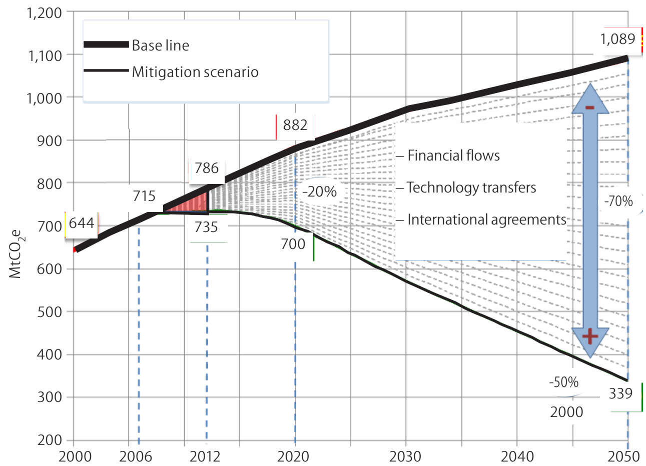
Year	Population, Billions	Max GHG Emissions $GtCO_2$-eq	Max Per Capita GHG Emissions tCO_2-eq
2000	6.11	42	6.87
2010	6.91	50	7.24
2020	7.67	50	6.52
2030	8.31	50	6.02
2040	8.80	48	5.45
2050	9.15	43	4.70

(1) Population projections correspond to "medium variant" UN estimates (UNPD 2008).
(2) Maximum GHG emissions correspond to the "phased 2030" scenario shown in Figure 4.
(3) Year 2000 values are actual data.

Climate Change Commitments

Climate change is real, and developing countries are more vulnerable to its impact. Already poor countries are suffering from increased floods and droughts (all over the world), rising sea levels (Pacific Islands, Bangladesh), etc. It is therefore in our own interest to promote policies where total GHG emissions worldwide decrease. This will require drastic decreases in emissions from industrialised countries and some commitment from developing countries. The key word here is "commitment" which does not necessarily imply reduction from current levels. In fact, though the European Union (EU) as a party to the Kyoto Protocol took on commitments to reduce its overall GHG emissions by 8% (from 1990 levels), it passed on these commitments at different levels among member states, requiring countries to reduce emissions by varying percentage values, and even allowing some countries to substantially increase emissions compared to their 1990 levels. Thus, Ireland was allowed to increase emissions by 13% compared to its 1990 level, Spain by 15%, Greece by 25%, and Portugal by 27%. Of course, other countries had higher emission reduction targets to compensate, e g, United Kingdom to reduce emissions by 12.5%, Austria by 13%, Denmark by 21%, Luxembourg by 28%.

Figure 5: Projected GHG Emissions for Mexico in a Business-as-Usual (BAU) Scenario and a Possible Mitigation Scenario, Where Reductions from the BAU Are Supported by Financial Flows, Technology Transfer and International Agreements



Source: Mexico (2009).

Thus, a commitment on emissions by developing countries need not be a reduction, but rather limit emissions increase by a specified amount in future years.

The Mexican government has set forth its proposal for climate change commitments in a recent report (Mexico 2009). The report cites the OECD (2008) study and Figure 4, noting that since Mexico is a middle-development country, its behaviour should be similar to what is needed for the world as a whole, i e, a reduction starting in the middle of the next decade, and deep cuts in emissions in future years, not only with respect to the baseline scenario, but also with respect to recent emissions.

Mexico has a population of about 111 million, with total GHG emissions of about 730 mtCO_2-eq (Figure 5), so that its per capita emissions are around 6.6 tCO_2/year, somewhat below world average (Table 1).

As Figure 5 shows, the Mexican government proposes to reduce its GHG emissions with respect to a business-as-usual scenario, provided there are financial flows and technology transfer (from developed countries) and an international agreement with wide participation among industrialised and developing countries (Mexico 2009).

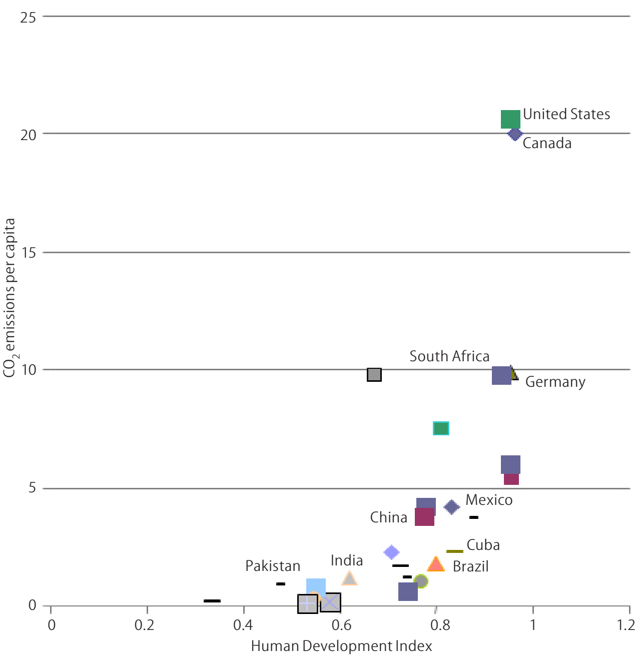
There are of course a number of issues with respect to this proposal. One is how to set the Business as Usual (BAU) scenario, or how to determine if the scenario is reasonable. Depending on assumptions, projections on emissions can vary greatly. It may be in the short-term interest of any country to make a commitment allowing for higher emissions, and developing countries are no exception. One way around this was suggested by Argentina at the UNFCCC Conference of the Parties in 1998 (designated COP4). According to the Argentina proposal, booed by all developing countries at the 1998 Conference, a developing country would commit to an emissions limit that was less than its GDP growth. Emissions would be limited as given by:

$$E(t) < E(0) \times \left(\frac{Y(t)}{Y(0)} \right)^{\kappa} \qquad ...(1)$$

where $E(0)$ and $E(t)$ are GHG emissions in year 0 and year t, respectively, while $Y(0)$ and $Y(t)$ are gross domestic products in the respective years, and the exponent "k" is less than one, and would be the number to be negotiated in a climate agreement.

According to this arrangement, any developing country reducing its emissions by more than its allotted amount according to Eq (1) could offer these reductions to another country to reduce their emissions, in much the same way as emissions are traded among Annex 1 countries who committed to emissions reductions under the Kyoto Protocol.

Figure 6: Per Capita Carbon Dioxide Emissions (2004) and Human Development Index (HDI, 2005) for Selected Countries



Source: UNDP (2007) Tables 2 and 24.

Since we have claimed that GDP is not a good indicator of development, another approach could take the Human Development Index (HDI), as defined and reported in the *Human Development Report*. Figure 6 shows the HDI and per capita CO_2 emissions from selected countries spanning the range of HDI. One can see that at high levels of HDI, close to its maximum value of unity, there is a large range in emissions per capita, from about 5 tCO_2/capita (e g, Switzerland) to above 20 (US and Canada). This suggests that it is possible to live well with far less emissions.

Since it is not possible to label countries crowded together in Figure 6, data for a smaller subset of countries are shown in Table 2. If we focus on India and its neighbours, shown in bold in Table 2, it is clear that China and Sri Lanka had substantially higher HDI (0.777 and 0.743, respectively) than the remaining countries (ranging from 0.619 to 0.534). India had the highest per capita emissions among the south Asian countries, and in fact twice as large as that of Sri Lanka, four times that of Bangladesh and 12 times that of Nepal. Notice that China's per capita emissions were six times that of Sri Lanka and triple that of India. The HDI score could be the basis for setting emissions limits. Thus a country with a low HDI would be allowed to emit more per capita provided that in future years its HDI improves.

Table 2: Per Capita CO_2 Emissions for Selected Countries in Decreasing Order of Human Development Index (HDI)

Country	HDI, 2005	tCO_2/Capita, 2004
Canada	0.961	20
Switzerland	0.955	5.4
Japan	0.953	9.9
France	0.952	6
United States	0.951	20.6
United Kingdom	0.946	9.8
Germany	0.935	9.8
Argentina	0.869	3.7
Cuba	0.838	2.3
Mexico	0.829	4.2
Brazil	0.8	1.8
China	**0.777**	**3.8**
Sri Lanka	**0.743**	**0.6**
Indonesia	0.728	1.7
South Africa	0.674	9.8
India	**0.619**	**1.2**
Myanmar	**0.583**	**0.2**
Bhutan	**0.579**	**0.2**
Pakistan	**0.551**	**0.8**
Bangladesh	**0.547**	**0.3**
Nepal	**0.534**	**0.1**
Nigeria	0.47	0.9
Sierra Leone	0.336	0.2
World average		4.5

India and its neighbours are shown in boldface.
Source: UNDP (2007): *Human Development Report 2007-08*, Table 2 and Table 24.

Princeton Approach

Another way to set an emissions limit, applicable to all countries, is suggested by Princeton University researchers. Recognising that people and their activities lead to emissions, not countries per se, Chakravarty et al (2009) have estimated the distribution of emissions among the world's 6.1 billion people (Figure 7, p 44). They note that in 2008, half of the world's emissions came from just 700 million people, each emitting over 10 tonnes of CO_2, and that about 2.4 billion people emit less than one tonne CO_2 per year, and the latter should not be put on a CO_2 diet. They further propose that countries be assigned emissions limits based on the emissions of individuals. This is illustrated schematically in Figure 8 (p 44). They do not propose limiting the emissions of individuals, but merely to establish limits on the country's total emissions. The approach does not specify how the limits are to be met and leaves the policies and measures for reducing emissions to the countries. Thus policies could direct emitters at all levels. The Princeton approach is presented in great detail with explanations of methodologies, data sources, etc, and is well worth studying (Chakravarty et al 2009). The approach may be difficult to apply for two major reasons. Income disparity is a major feature of underdevelopment. Therefore, reliable indicators of income variations may not be available in many countries. Another issue is determining individual emissions. People emit directly through energy purchases for their houses and for any vehicles they may own. However, there are many indirect uses of energy, and it is not straightforward to know, how the associated indirect emissions are distributed among the population. This author believes that this approach is not ready for immediate application.

As we have already noted, India's per capita emissions are far below world average, and five recent modelling exercises all indicate that BAU per capita emissions are likely to remain far below today's world average, and below the upper limit of world per capita emissions at least until 2030, as shown in Table 1 and Figure 9 (GOI 2009).

Figure 7: Emissions as a Function of Cumulative Population

Some 700 million emit more than 10 tonnes CO_2 per year, while at the other end some 2.4 billion people emit less than 1 tCO_2/year

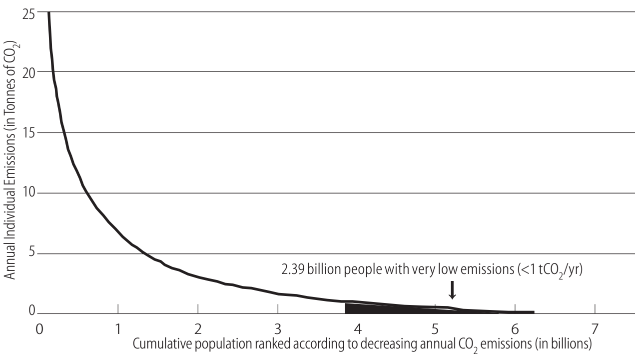


Figure 8: Country Emissions Targets Based on Individual Emissions

The proposal establishes a uniform "cap" on emissions that individuals should not exceed (represented by the line). If, for example, an international treaty caps global emissions at a certain level, the necessary reductions in global emissions could be achieved if no individual's emissions could exceed a certain "cap." By counting the excess emissions of all the individuals who are projected to surpass the "cap", the proposal provides emissions reduction targets for each country.

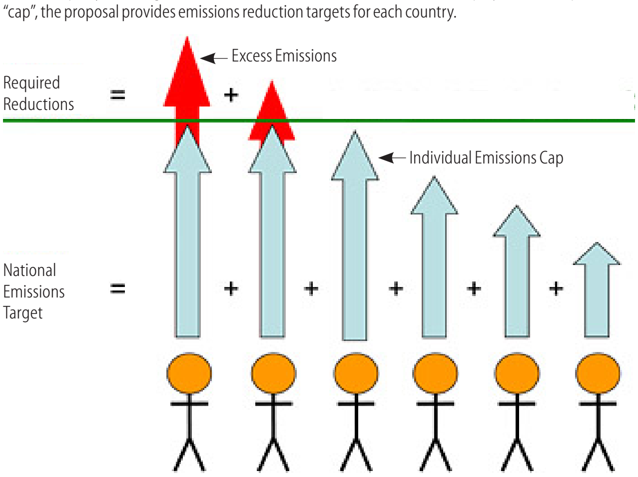
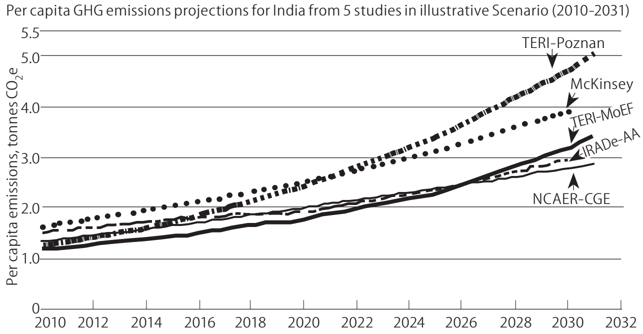


Figure 9: Five Different Projections of Per Capita GHG Emissions in India, 2010 to 2031

Only the McKinsey study considered methane emissions from agriculture



Source: GOI (2009), Exhibit 1.

Projected total BAU GHG emissions according to these five studies are shown in Figure 10 (p 45). As in the Mexican proposal, these projections could be the basis for a BAU scenario, and climate negotiations whereby India would be willing to reduce emissions further, through financial flows from industrialised countries.

While India's per capita emissions are low, the scenarios indicated in Figure 10 suggest that it could reach 3.5 tCO_2-e per capita or more by 2030. Keeping in mind that all developed countries and many developing countries are considerably higher now and the whole world needs to go down to, say 6 tCO_2-e per capita by 2030, it is clear that developing countries cannot continue to increase their emissions indefinitely. This is confirmed by a modelling exercise reported by Kanitkar et al (2009), where they divide the world into regions, and consider various stabilisation scenarios. They conclude

> Even if the Annex-I countries undertake substantial cuts in their emissions (cut emissions in 2020 to 40% below 1990 levels), the long-term atmospheric concentration levels depend significantly on the behaviour of the Emerging Economies. For total global emissions to decrease early on, early reduction in the growth rate of emissions from the Emerging Economies appears necessary.

Loose Ends

In the discussion so far we have left behind some loose ends, and let us review these next. The industrialised countries were able to reduce total GHG emissions since 1990. These countries as a whole, and the European Union, in particular, are likely to meet their commitments under the Kyoto Protocol. However, this was possible in part because the emissions of the former communist countries of the Soviet Union and eastern Europe fell drastically in the years following 1990. If we exclude these countries, overall emissions of industrialised countries increased substantially since 1990, despite a significant reduction in emissions intensity. Emissions in developing countries also increased substantially, most likely also with a significant reduction in emissions intensity. Here we are not considering "transfers" of emissions reductions from developing to industrialised countries, through the Clean Development Mechanism (CDM), discussed later. The conclusion is that, overall, technologies and policies implemented since 1990, and especially since the Kyoto Protocol, are unlikely to be adequate to meet the needed future decrease in world GHG emissions in order to stabilise climate.

One loose end we have not commented on is that since 1990, China's manufacturing sector has grown considerably, and since a significant part of China's production is exported, especially to industrialised countries, this has led to increased emissions in China and reduced emissions in those countries whose manufacturing base has shrunk because of Chinese imports. Of course China is not the only exporter of manufactured goods, and only illustrates one difficulty in assigning emissions limits to countries, without taking into consideration the effects of trade.

Another loose end that we have not mentioned comprises CO_2 emissions and sinks that cannot be ascribed to a national inventory. The most important in this category derive from the combustion of so-called international bunker fuels that are used in international aviation and shipping. In 2004, they added up to about 1 Gt CO_2, about the same as India's CO_2 emissions. Emissions from aviation and shipping are comparable, both have grown considerably since 1990, and are expected to grow fast in future years. This year, the European Union included aviation emissions within its Emissions Trading Scheme (EU ETS), requiring inventories of such emissions from all flights into or out of EU member states, with the goal of limiting emissions from 2012.

Another loose end calling for comments is with respect to CO_2 versus other GHGs. Some of the discussion was based on CO_2 emissions while others apparently took into account other GHGs, at least by referring to "CO_2-eq" emissions, where "eq" means that all GHGs have been added up on the basis of their CO_2 equivalent mass.

According to the IPCC (2007, Chapter 1, Figure 1.1a), total GHG emissions in 2004 added up to about 49 GT CO_2-eq of which only about 28 GT CO_2 was CO_2 from fossil fuel use. Another 2 GT CO_2 was from industrial processes (mainly cement manufacture). A further eight GT CO_2 was emitted by biomass decay including deforestation. Discussions on climate change mitigation often focus almost exclusively on CO_2 emissions from fossil fuel use. Notice, e g, that the Princeton approach only considered individual CO_2 emissions (Chakravarty et al 2009). If we look at the model and the assumptions behind the five modelling exercises undertaken in India, it appears that, in general, only CO_2 emissions from fossil fuel use were considered. (As noted in the figure captions to Figures 8 and 9, only one of the models considered methane emissions from agriculture.)

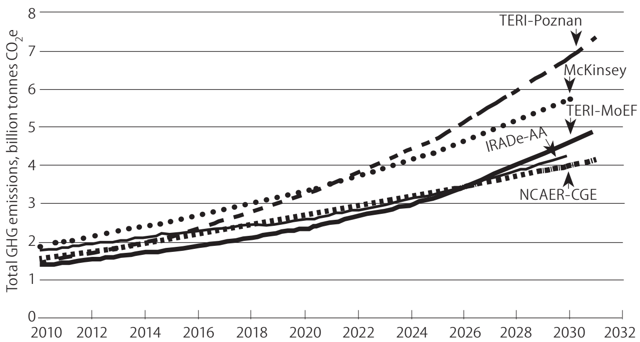
As noted above, IPCC (2007) assigned eight out of 49, i e, 16% of total GHG emissions to biomass decay and deforestation. Forests and rangelands can absorb CO_2 from the atmosphere, while their destruction releases CO_2 to the atmosphere. Overall, the processes are called LULUCF. These comprise another loose end. The CO_2 emissions from fossil fuel combustion are very easy to determine, simply from the consumption and carbon content of each fuel, virtually all of which is converted to CO_2 and released. The uncertainty with respect to LULUCF emissions or sinks are so large that UNFCCC reports national emissions separately, including and excluding LULUCF (as we commented earlier), and the results are substantially different, i e, total national emissions change considerably from one to the other, so that the extent to which individual countries can meet their Kyoto Protocol commitments also changes dramatically.

The effects of LULUCF are likely to be large, especially in forested countries, and where land use is changing quickly. For instance, the sharp increase in food prices in 2008 led to considerable expansion of the agricultural frontier in many South American countries, mainly for soyabean cultivation, and though reliable estimates of net CO_2 emissions are not available, they are almost certain to be significant (Rosenthal 2009; *The Economist* 2009). The CDM recognised and financially rewarded certain types of emission reduction projects in developing countries, but does not so reward forest conservation. At present there is an initiative called Reducing Emissions from Deforestation and Degradation (REDD) which would allow incentives for protecting existing forests. It would be very important to maintain this type of incentive to protect forests in developing countries, in any post-2012 climate agreement. There is considerable pressure on large developing countries, including Brazil, to adhere to a climate change agreement. Such negotiations should take note of the fact that Brazil's energy related CO_2 emissions are small (because of a very large renewable component) and is much smaller than their net CO_2 emissions from deforestation. Tropical rainforests provide many other benefits besides holding carbon out of the atmosphere. These include biodiversity, and often the protection of indigenous cultures. Keeping this in mind, Ecuador (for which too deforestation CO_2 emissions are over twice as large as energy CO_2 emissions) has proposed an initiative whereby it would be paid to conserve virgin rainforest and protect a tribe that has not come into contact with the outside world. EPW has reported on this earlier (Alier 2007; Alier and Temper 2007).

Figure 10: Five Different Projections of Total GHG Emissions in India, 2010 to 2031

Only the McKinsey study considered methane emissions from agriculture.

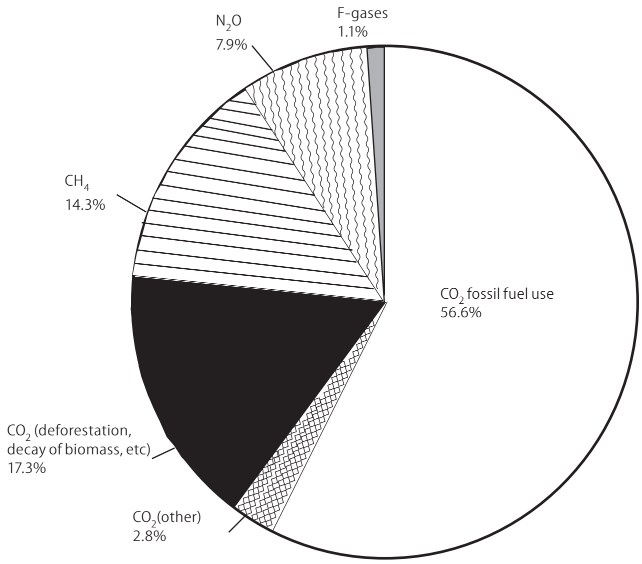
GHG emissions projections for India from five studies in illustrative Scenario (2010-2031)



Source: GOI (2009), Exhibit 2.

Thus, according to IPCC (2007), CO_2 emissions in 2004 added up to 38 GT, with another 12 GT CO_2-eq (*and note that we have now added the* "*eq*") from other gases. Of these, methane is the next most important, adding about 7.5 GT CO_2-eq in 2004, 17.3% of the total. A third of this is from energy (e g, biomass burning can release large quantities of methane). A little over a third is from agriculture and the remainder (a little under a third) from solid and liquid wastes, industrial processes, etc. Except for agriculture, these emissions are not linked directly to production, and therefore make no contribution to the economy. We will come back to agriculture further below. Emissions from solid waste disposal (e g, landfills) can be greatly reduced and indeed the methane recovered can be used as energy, thus not only reducing methane emissions but saving energy and offsetting carbon dioxide emissions from fossil fuels use elsewhere. Similarly "fugitive" methane emissions from coal mines and natural gas production and use can be reduced or captured, again with positive benefits.

Figure 11: Global Anthropogenic Greenhouse Gas Emissions in 2004



Source: IPCC (2007), Figure 1.1b.

The third most important GHG is nitrous oxide, mostly emitted in agriculture. The remaining GHGs considered by the IPCC (2007) and also covered by the Kyoto Protocol are the so-called F-gases: HFCS, PFCS, and SF_6. They are all man-made and contributed less than 1 GT CO_2-eq in 2004.

Agriculture produces substantial GHG emissions in a variety of ways. Nitrogen fertiliser production normally involves ammonia synthesis and nitric acid production, requiring large amounts of energy (and hence generating CO_2 emissions), while nitric acid production emits nitrous oxide. Nitrous oxide is also released from fertiliser application to fields. Rice fields emit methane through the anaerobic fermentation of biomass in flooded fields, similar to methane production in a biogas plant, where of course it is not released into the atmosphere. Ruminant animals (e g, cows) produce methane in the digestion process, and this methane is released into the atmosphere. All these emissions can be reduced through a variety of processes.

Figure 11 is a reminder that CO_2 from fossil fuel use is not the only GHG source, and discussions should neither ignore CO_2 from other sources, nor the other GHGs. Furthermore, reports should not pretend to include other gases, by incorrectly using the expression "CO_2-eq".

The Way Forward

We can now put all this together into a proposal for moving forward on international commitments on climate change. The proposal should be discriminated among the different GHGs, in part because of uncertainties in their measurement.

F-gases: HFCS, PFCS, and SF_6 all have very high global warming potential, thousands of times that of carbon dioxide. Mitigation can be highly cost-effective, and such projects have made a major participation in the CDM. Indeed some projects are so cost-effective that CDM has been accused of creating windfall profits. The counterargument is that these projects have led to very substantial reduction in CO_2-eq emissions, e g, almost 0.5 G tCO_2-eq in only 23 HFC projects expected up to 2012. This reduction potential is virtually identical to that of 1,242 hydroelectric projects in the CDM pipeline (UNEP 2009). The argument over whether these F-gas projects were very cost effective or too cost-effective is now irrelevant, since (a) virtually all such projects have already been implemented, and (b) CDM rules do not allow products in new production facilities or increase in production over historical levels. We propose that further mitigation projects involving these gases be undertaken using the model successfully applied to ozone depleting substances, through the Montreal Protocol, or simply by extending the mandate of the Global Environment Facility (GEF) to include these gases. Indeed, the Montreal Protocol has already taken over responsibility for future HFC emissions, with details of how the Montreal and Kyoto Protocol would work things out currently pending (PointCarbon 2009). We propose to extend this type of arrangement so that industrialised countries could provide technologies and fund projects to reduce the emissions of all F-gases. Moreover, the emissions of F-gases should not be a part of any future emissions agreements covering developing countries, or if they are, they should be treated separately. This is necessary since future emission reductions of these gases have already been committed by developing countries through their participation in CDM projects. See "CDM aftermath" further below.

Industrial Emissions of Nitrous Oxide: e g, in nitric acid manufacture should be subject to a regime similar to that applied to the F-gases.

IPCC (2007) notes that the uncertainty in estimates for methane and nitrous oxide emissions in agriculture is quite large (of the order of 30-50%) and even larger for CO_2 from agriculture and forestry. Therefore, agriculture and forestry deserve separate treatment, not ignored. Given the large uncertainties, instead of creating GHG emissions tables with and without LULUCF, and scratching our heads on which table to consider, let us keep the data separately, for reliable emissions (CO_2 from energy consumption and industrial processes, methane from industrial processes, waste, coal mines and natural gas systems, F-gases) and for currently uncertain sources: agriculture and forestry.

Agriculture: CO_2 and nitrous oxide emissions from fertiliser manufacture should be counted as reliable, and not considered here. The remaining emissions from agriculture are mostly methane (rice fields, ruminants) and nitrous oxide (fields). A separate fund could support R&D and demonstration projects involving methane and nitrous oxide emissions reduction. These could involve technology transfer from industrialised countries, other developing countries, as well as development within our countries. The International Rice Research Institute (IRRI) is an example of the type of institution that can be supported through this fund. IRRI has of course been working on the question of methane emissions from rice production.

Forestry: Forestry emissions can be very large, while forests are potentially large sinks to atmospheric carbon dioxide. Besides keeping separate data on forest emissions and sinks, a separate fund needs to apply, in the first instance to preserve virgin rain forests, then other types of forests. We have already mentioned the Ecuadorian "Yasuni ITT initiative" as an example of the type of projects to be supported. Since there are often local economic benefits to cut down forests, we need an incentive structure that counteracts these incentives, perhaps supporting development of other economic activities that do not require felling trees, and in all cases supporting biodiversity.

Carbon Dioxide (Other Than Agriculture and Forestry): The previous paragraphs leave out the bulk of emissions. We have already presented the Mexican proposal, whereby a country makes a commitment to a certain BAU emissions scenario, with incentives to emit below this level. While the definition of a believable BAU scenario may be controversial, the five Indian scenarios illustrate that different scenarios may not diverge that much, as long as consistent assumptions are applied, and are limited to CO_2 emissions only. While one of the five scenarios was developed by a group from outside India, it is possible to have BAU scenarios developed by groups of international reputation and audited by others. Furthermore, to reduce bias, actual emissions limits could be set in such a way that the maximum emissions of a group of countries does not far exceed or fall far short of the average of other countries in a similar stage of development. Since the eventual goal would be to converge on uniform per capita emissions across countries over several decades, as suggested by the Global Commons Institute (GCI) and supported by the government of India, the agreement would require large emissions cuts, and soon for those countries with current levels greatly exceeding the allowable limit (see Table 1), while those at the other end of the emissions spectrum, have a large room for manoeuvre as they progress along the development path.

CDM and Beyond

The participation of developing countries in the Kyoto Protocol has been through the CDM. Before exploring what might happen in the future, let us review how CDM works. Qualifying emissions reduction projects (and sets of projects called programmes) can earn revenues from the sale of so-called Certified Emissions Reductions (CERs) to Annex 1 parties (countries, or organisations within them) who can use them to meet a part of their emission reduction commitments under the Kyoto Protocol. Since developing countries have not made any commitments on their emissions under the Kyoto Protocol, these CERs currently have no relevance for their GHG inventories.

The CDM project development approval process is cumbersome (see e g, Dutt 2006; Iannariello et al 2008). Thus each of the 1,242 hydro projects formally presented to the CDM (and listed in UNEP (2009) had to be presented separately, and go through the tedious approval process. "Umbrella projects" grouping several projects within a single package and seeking approval together help somewhat, but each component has to be approved, and if they are not executed simultaneously, CERs are lost from some components. The recently introduced programme modality (called CDM Programme of Activities) could permit smaller projects to participate, but it is too early to say how much simpler this might be, and it is unclear if the process will reach maturity by 2012.

Since developing countries have no emissions commitments under the CDM, one essential requirement of the CDM process is that project emissions are below hypothetical baseline emissions, a process called "additionality". Since baseline depends on existing government policies that could affect GHG emissions, this has led to contradictions and possibly perverse situations. Governments may put off taking decisions to lower GHG emissions, for example by reducing methane emissions from landfills, for fear of losing additionality. Thus, countries that are more active in measures that reduce GHG emissions are penalised, insofar as they are able to credit fewer CERs, or none. Even private initiatives to reduce emissions are penalised through the CDM. For instance, the International Aluminium Institute (IAI) set forth voluntary targets for reducing PFC emissions in aluminium smelting, and member companies adhering to these standards can claim no CERs, since the CDM baseline is set at the IAI voluntary target level.

One way of demonstrating additionality is to show that a proposed CDM project is not cost-effective, compared to alternatives. This leads to the perverse situation where, say, a wind power project that is not cost-effective qualifies for CERs, while a more profitable project is denied them. In principle, CDM rules presume that if a project were profitable, it would be implemented anyway, without the need for CER revenues. This may not happen.

Some of these difficulties could be overcome through a sectoral approach, where rules are defined at the sectoral level, so that each project need not be evaluated individually. For instance, electric power generation emitted 10 $GtCO_2$ in 2004 (IPCC, Figure 1.2), the single largest such sector, accounting for a fifth of all GHG emissions, worldwide. Well over half of all CDM projects in the pipeline (and almost 65% of all Indian projects) involve power generation (UNEP 2009). Amatayakul, Fenhann and Berndes (2008) and Amatayakul and Fenhann (2009) make a very interesting proposal for a sectoral approach to providing incentives to developing countries to reduce emissions in this sector beyond 2012. Since India's electric power sector is coal-based, and therefore emissions-intensive, and India has been very proactive in reducing emissions (recall how new power plants emit only about 60% of the average of all existing power plants), a sectoral approach would be highly beneficial to India, compared to the current situation where each hydro, wind or high efficiency natural gas power plant project has to go through a three-year process with no guarantee of approval at the end of the pipeline.

A Commitment Regime

In a post-2012 regime whereby developing countries take on commitments to limit future growth in emissions for energy-related

CO_2 emissions, according to some formula (including per capita emissions and GDP), the situation will be substantially different than in the current CDM regime. In a commitment regime, developing countries will face a situation similar to that faced by Annex 1 parties (industrialised countries) under the Kyoto Protocol. The most important is that countries would be responsible for their total emissions. Thus, the national inventories would become very important. Each country would then determine how it would meet its emissions limit. The European Union, as an example of an Annex 1 party under the Kyoto Protocol, assigns emissions limits to emissions intensive sectors, allowing them to trade emissions so that emissions reductions can be achieved in the most cost-effective manner. California, which has taken on commitments on emissions reduction, has taken a broader and more pragmatic approach, considering mandatory requirements (e g, for industrial gases, equipment energy efficiency standards), emissions trading, as well as voluntary programmes (California 2006; CARB 2009).

Since emissions reductions would be credited against a national emissions inventory, a commitment regime would not permit project-based emissions reduction incentives, such as the CDM. Nor would project-based systems such as Joint Implementation (JI) be applicable since most developing countries are unlikely to have large "excesses" of emissions reductions. Most JI projects in the pipeline are in countries of the former Soviet Union and eastern Europe, who currently hold such "excesses". Countries approve JI projects only if they are confident that they are well below their commitments. Thus, New Zealand approved a few JI projects initially before they realised that they might not meet their Kyoto Protocol targets.

CDM Aftermath

A post-2012 commitment regime has an impact on CDM projects approved and implemented prior to 2012. The crediting period of CDM projects can be as many as 21 years. CDM programmes can credit even longer. Since there is no agreement to follow the first commitment period of the Kyoto Protocol, which expires on 31 December 2012, at present there is uncertainty on the value of CERs beyond 2012. It is generally believed that there will be a market for CERs or something equivalent, since the EU is very likely to recognise such credits issued under the Kyoto Protocol. Moreover, the US policies on climate change mitigation, currently being discussed by their legislature, are also likely to include emissions offsets, such as CERs (HR 2998, 2009).

Since we all share the atmosphere and GHGs mix relatively quickly within it, emissions reductions anywhere helps mitigate climate change. Hence, it makes sense to allow for flexibility in obtaining emissions reductions anywhere in the world. However, in order to seek an emissions reduction outside a country (and lose local economic benefits of the mitigation activity), the opportunity needs to be substantially more cost-effective elsewhere. This may not always be the case. For instance, a wind generator costs about the same anywhere in the world, and the energy it produces depends on the available wind. Thus, it would make sense to install wind power elsewhere, only if there is a very favourable wind regime, or the emissions factor of the host country is high, e g, because of a high proportion of coal power plants. It is not clear what the potential for emissions offsets is, and how they would be selected.

For reasons explained in the previous section, in a commitment regime developing countries are unlikely to approve project-based mitigation opportunities unless governments are firmly in control, and are confident that they have surplus emissions reductions. This is because any emissions reduction in a host country sold to offset emissions in another country, means that the applicable emissions inventory of the host country is increased by the amount offset.

Thus, in a post-2012 commitment regime, any CERs issued after 2012 would increase emissions of the host country. If all are approved, CDM projects currently in the pipeline are expected to generate 2.78 $GtCO_2$-e in CERs by 2012, and another 4.56 $GtCO_2$ by 2020 (UNEP 2009). Many projects are also expected to deliver credits beyond 2020. In any case, it is clear that any post-2012 negotiations should take into consideration the post-2012 potential CERs. It would make a great deal of difference to the commitments of a developing country if those post-2012 CERs, used to offset emissions in other countries, increase their overall emissions and therefore increase their commitments to reduce below their BAU scenario, or not.

Conclusions

Global emissions of GHGs need to decrease substantially and soon, if we are to stabilise climate at reasonable acceptable levels. The Convergence and Contraction approach appears to be a reasonable ethical basis for assigning future emissions limits. Countries with per capita emissions far exceeding limits required to stabilise emissions (Table 1) would need to reduce their emissions drastically over the next few decades. While many developing countries have generally low per capita emissions, for emerging economies these are rising quickly. For instance, China's per capita emissions in 2004 were close to global average value (Table 2). Developing countries should be willing to make a commitment limiting future emissions of carbon dioxide, and countries with currently low per capita emissions, such as India, this commitment could allow for substantial increase over the next couple of decades. Business-as-usual projections of CO_2 emissions in India suggest that these emissions are growing far smaller than GDP, and could be the basis for establishing emissions limits. Developing countries emitting below their limits could be financially rewarded on the basis of their overall emissions, or through a sectoral approach covering electric power generation, transportation and other sectors responsible for most CO_2 emissions. While the analytical procedure is cumbersome, it can be accomplished and audited by teams from other countries. Emissions from international aviation and shipping should not be ignored, even though these emissions cannot be charged to any specific country. A separate regime is suggested for emissions of F-gases and industrial N_2O emissions. Because of large estimation uncertainties, emissions or sinks from forestry and emissions from agriculture should be covered by separate agreements, but not ignored.

Getting to a binding agreement acceptable to all or most countries is not going to be easy. Certainly, it will not be easier than the Kyoto Protocol, which required no quantitative commitments from developing countries, only potential rewards through the CDM. Despite modest commitments on emissions reductions, the Kyoto Protocol provides us with valuable insight. Many countries failed to meet even these modest commitments. Almost everyone agrees we need to do a lot more. The next step might be a modest agreement, on a shorter scale, say, up to 2020, to see if we can do any better than we did under the Kyoto Protocol. The new agreement should seek greater commitments on countries with high per capita emissions, and emissions growth limits on developing countries whose per capita CO_2 emissions exceed, say, 1 tonne/capita. As a large country with an emerging economy, India can take a proactive position to make this happen.

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