neither trapped nor when they escape in all directions being not confined. Yukolov and Yukolova have analysed the situation and arrived at some interesting conclusions:

- *the particles can escape only in the positive Z-direction.*
- *motion along the axial direction is much faster than along the radial direction.*

Numerical calculations have provided much detailed insight. These have shown, for example, that a well collimated narrow beam is formed, being stretched in the axial direction more than an *order* of magnitude stronger than in the radial one. Choice of characteristic parameters of the magnetic fields is also discussed.

In summary, in ref. 6, a new general mechanism for creating a well collimated beam of neutral particles using magnetic fields is proposed.

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COMMENTARY

Kyoto agreement on greenhouse gas reduction and future global temperature and sea-level trends

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The global warming issue has been taken up at several intergovernmental conferences, focussing on climate changes in the 1990s. The Intergovernmental Negotiating Committee (INC) met five times before the United Nations Framework Conversion on Climate Change (UN-FCCC) was adopted in June 1992 at the Rio Earth Summit. Under this convention, it was decided that national greenhouse gases (GHG) emission inventory, as well as the strategies being adopted to deal with mitigating the induced climate changes should be reported by the governments of all signatory countries to the FCCC Secretariat. The industrialized countries (ICs) for the first time agreed to commit themselves to a legally binding schedule for the reduction of CO_2 emission. At the Conference of Parties of the UN-FCCC held at Berlin in 1995 the Berlin proclamation, also known as the 'Berlin Mandate', became the basis for future negotiations on climate changes. It placed responsibility on developed nations for setting specific targets for reduction of the GHG emissions. Although at the second Conference of Parties in 1996 the US's stand appeared positive, it soon began supporting a proposal by Germany which asked for simultaneous curbs on emissions by developing countries (DCs) like India, China and Brazil. They argued that the GHG emission from these countries is likely to be at a much higher rate in the future, and therefore this would neutralize any tangible reductions by the ICs. The European Union (EU) led the subsequent negotiations in providing a just argument for short-term targets for reduction of the GHG emission. In March 1997, the EU formally proposed that for the ICs legally binding cuts in emission of three major GHGs, namely, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), should be set at 7.5 per cent below the 1990 levels by 2005, and at 15 per cent by 2010. On the other hand, Japan's proposal included a 5 per cent legally binding cut in GHG emission below the 1990 levels by the year 2008–2012, and further suggested flexible timetables for each country based on their economic output (gross domestic product) or population (per capita emission). Meanwhile, the G-77 and China continued to stress the underlying aspects of the Berlin Mandate such as joint implementation, emissions trading and emissions budgeting.

India brought up the issue of equitable emission rights and entitlements based on per capita emission both prior to and at the time of negotiations during the third Conference of Parties (COP 3) in Kyoto, Japan, 1–10 December 1997. Although several countries from Africa, Asia, and South America backed this proposal, USA expressed strong disagreement. Finally, an agreement was reached amongst all the delegates of the COP 3 on the last day of the meeting in Kyoto. Japan agreed to reduce its GHG emission by 6 per cent below the 1990 levels, US agreed for 7 per cent reduction, and the EU agreed for 8 per cent reduction by 2008–2012. The outcome of this agreement was achieving a net reduction target of 5.2 per cent in GHG emissions by the ICs by the year 2010. The DCs however were exempted from any commitment for reduction in their GHG emission level. During the COP 4 on UNFCCC, held in Buenos Aires, 2–14 November 1998, India and China –

the two key DCs – were however asked to 'participate meaningfully' in the global effort to reduce the carbon emission level. Unfortunately, India and China have the world's largest number of poor people and, therefore, they need the maximum opportunity to increase their energy consumption in the future. Also, together with any other African and South Asian countries they have the maximum stake in ensuring equity in sharing the burden of commitments to reduce the GHG emission.

Given the fact that carbon emissions are strongly, though not entirely, related to economic growth and standard of living, and further, many of the developing countries, whose participation is being sought, are amongst the poorest countries in the world needing the maximum 'economic space' and 'environmental space' to grow; sharing the economic burden and environmental space for combating climate changes becomes a critical issue. For developing countries, it might be impossible to forsake the economic and environmental rights of their future generations. They cannot accept a freeze in current global inequality. Thus, it is obvious that this isue can only be addressed through solutions that are both 'equitous' and 'ecologically effective' (i.e., effectively solve the global warming problem). It is quite obvious that without equity it is quite unlikely that there will be a long-lasting partnership between the ICs and DCs to address and solve the global CO_2 emission problem.

On the basis of the Kyoto agreement, GHG reduction commitments by the ICs and possible future options for the DCs, various scenarios for trends in the global CO_2 emission reduction upto the year 2100 have been worked out and used here to evaluate their implications on climate changes. The emission data for CO_2 emission by both ICs and DCs for the years 1990 to 1995 has been taken from *World Resource*[1]. A 1% growth per year in CO_2 emission by ICs has been considered from 1996 to 1998. A linear 5.2% cut below the 1990 emission level in CO_2 emission has been assumed by ICs from 1998 to 2012. For adoption of CO_2-emission-control strategies of DCs, we have considered two options: (i) that CO_2 emission at a growth rate of 3% per year be allowed until the per capita emission of the DCs

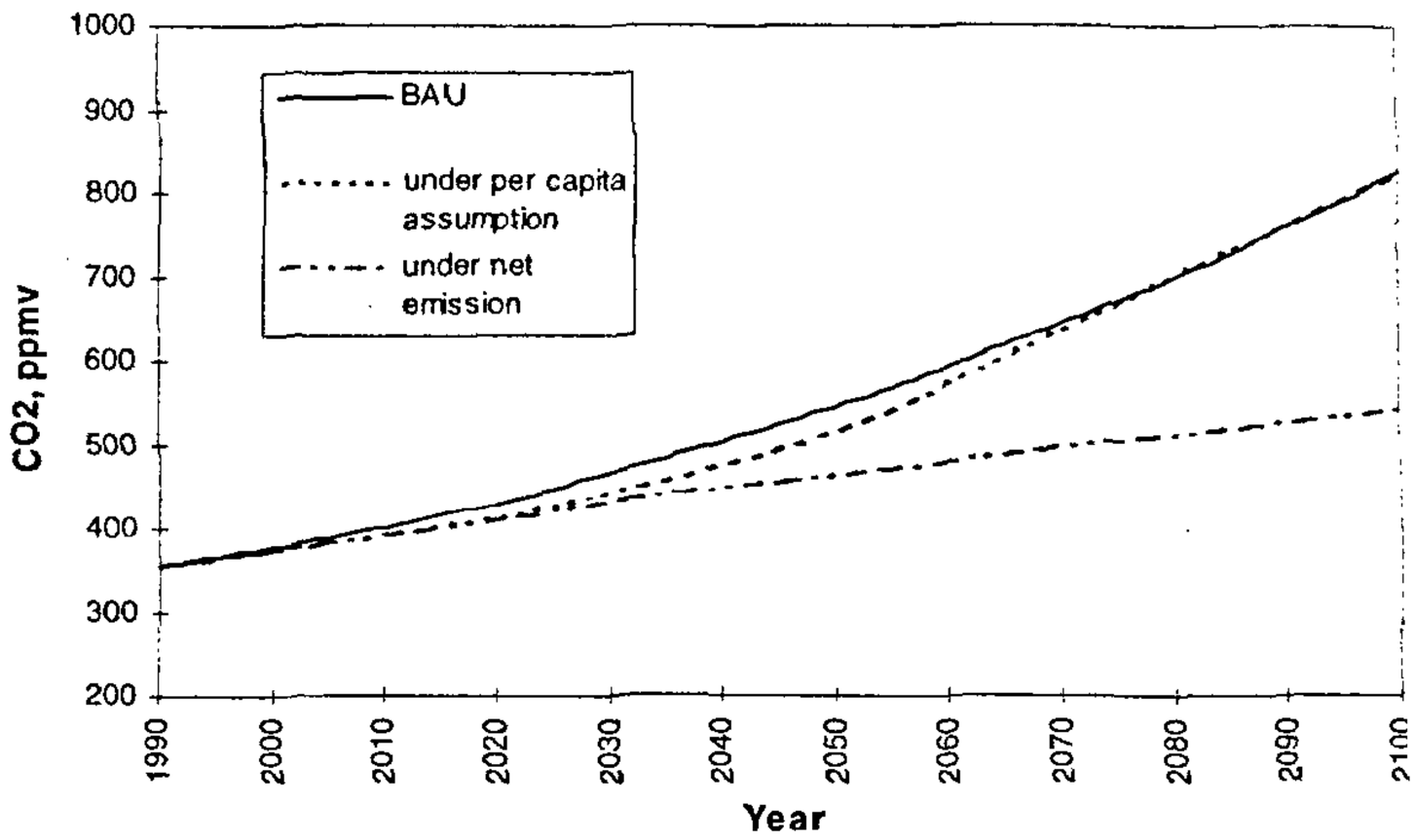

Figure 1. Global CO_2 concentrations for different scenarios such as BAU, per capita and net emission assumptions as estimated from climate model.

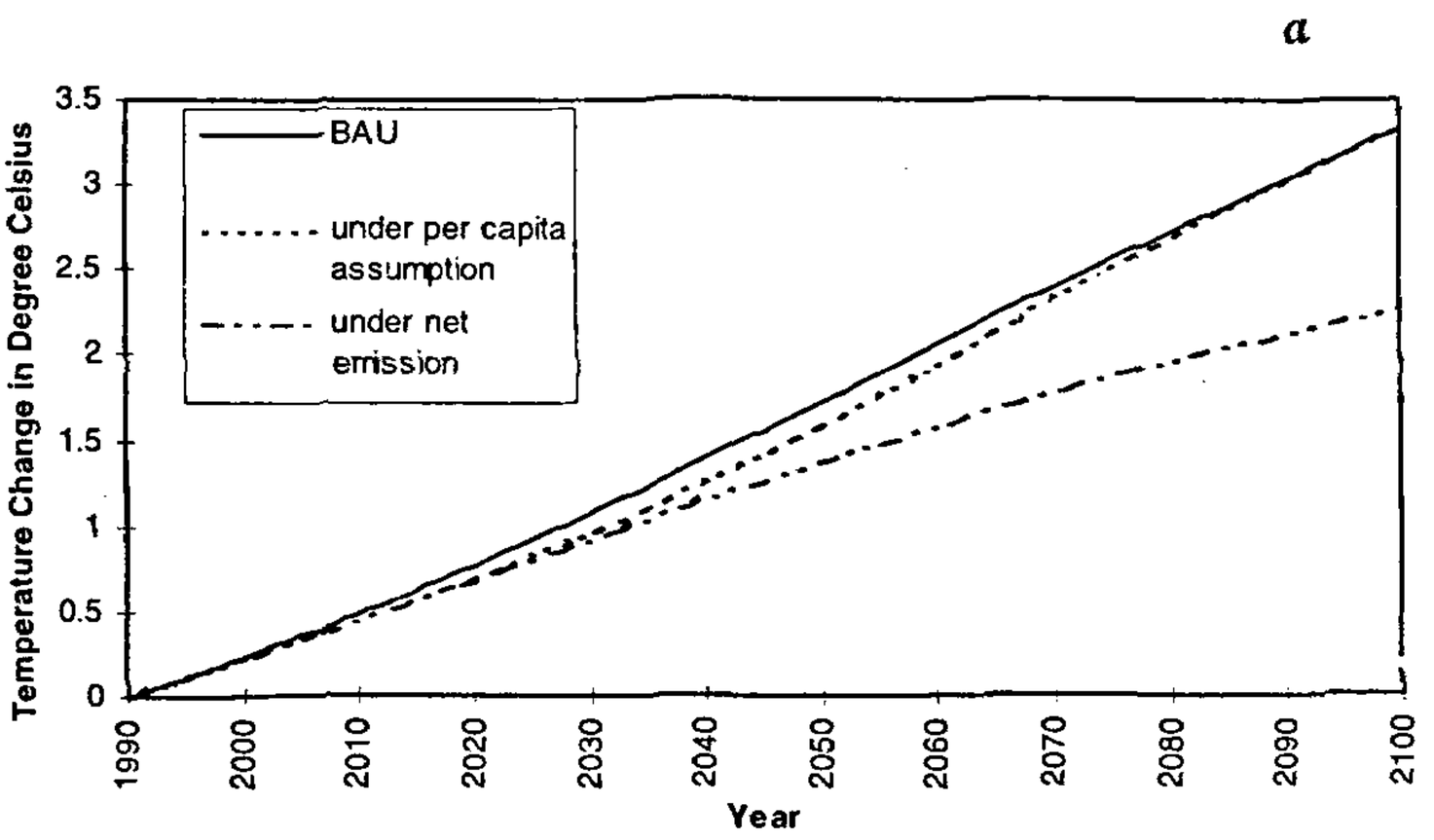

Figure 2. ***a***, Global temperature change as computed from simple climate model scenarios for BAU, per capita and net emission assumptions; ***b***, Global mean sea-level changes for various scenarios e.g. BAU, per capita and net emission assumption computed from climate model.

matches those of the ICs and thereafter it stabilizes. (ii) That CO_2 emission continues at a growth rate of 3% per year until the net emission of the DCs exceeds that of the ICs and thereafter and until 2100 both ICs and DCs stabilize their CO_2 emission level.

The CO_2 emission growth at a 3%/yr rate by DCs considered here matches our estimates for emissions from non-annex I countries for the period from 1990 to 1995. The population scenario (IIASA-A10 Quantification) for both annex I and non-annex I countries has been taken into consideration by the IPCC Working Group III Special Report on Emission Scenarios[2] to calculate the per capita emission for both the ICs and DCs. Using these CO_2 emission scenarios as input in a simple climate model (SCM), we have obtained changes in the future global CO_2 concentration, and thereby have obtained corresponding changes in the global mean temperature and sea level. The simple climate model used here to provide projections for global mean temperature change and sea level change response to the BAU emission scenario and carbon dioxide (CO_2) stabilization profiles contains modules that calculate: (i) the concentrations of greenhouse gases for given future emission; (ii) the radiative forcing resulting from the computed greenhouse gas concentrations and aerosol precursor emissions; (iii) the global mean temperature response to the computed radiative forcing; and (iv) the sea level rise due to thermal expansion of sea water and the response of glaciers and ice sheets. Further details on SCM can be found in IPCC Technical Paper II (ref. 3).

Under the BAU scenario, the CO_2 concentration is likely to reach a level of 825.42 ppmv by the year 2100 (Figure 1). When we consider a 5.2% reduction in the CO_2 emission from the 1990 level by the ICs and 3% growth per year for the DCs till per capita emission from the DCs is comparable to that of the ICs and then stabilize the net emission from both the ICs and DCs thereafter; no change is obtained in the CO_2 concentrations compared to those under BAU scenario. In the year 2063, the per capita emission of CO_2 from DCs equals that from ICs (Figure 1). In another case, when we consider a 5.2% reduction in CO_2 emission from the 1990 level by the ICs and 3% growth per year for the DCs till the net emission from the DCs is comparable to that of the ICs and stabilize the emissions from both the ICs and DCs thereafter; a concentration of 542.88 ppmv is attained by the year 2100. This is lower by 5% compared to the BAU scenario.

Simple climate models suggest a global warming of about 3°C and a sea level rise of about 68 cm by the year 2100 due to the CO_2 emission projected under the BAU scenario (Figures 2 *a* and *b*). In the first scenario, where we have considered the equity between the ICs and DCs on per capita emission basis, no change in the magnitude of global warming or sea level rise is obtained in our model calculations. The only difference between BAU and our scenario is that the rate of global warming as well as sea level rise are slightly slower in the latter case. In the scenario where we have considered the equity between the ICs and DCs on net emission basis, the global warming in the year 2100 is reduced to only 2°C. Similarly, a sea level rise of only 54 cm is obtained in this scenario.

These findings strongly suggest that we still need to examine more critically the CO_2 emission reduction/stabilization strategies for both the annex I and non-annex I countries if we are serious about making a significant dent in the projected rate of global warming and associated sea level rise. Today, there are many potential policies to reduce GHG emission for which total benefits outweigh the total costs. Moreover, given the socio-economic inertia in the energy system, a delay in abatement measures may prove costlier. It is true that onus of reduction in GHG emission lies with the ICs as it is they who are sole contributors to the current build up of GHGs in the atmosphere. The situation demands that if we have to arrest the global warming, the ICs have to adopt to more stringent mitigation strategies. The current growth rate for CO_2 emission is highest for India and China among the non-annex I countries. Therefore these countries have to play a dominating role in finding ways and means to curtail GHG emissions in non-annex I countries. The need of the hour is to follow a sustainable development path wherein the targets should be focused on attaining the higher energy efficiency in non-annex I countries. Our industry sector has a major role to play to ensure CO_2 emission control by enhancing energy efficiency.

An effective strategy to arrest global warming is to follow the principles of 'convergence' and 'equitable entitlements'. The ICs need to accept an urgent change in their domestic energy trajectory and undertake more stringent GHG emission reduction targets. Every effort to delay puts the world, especially its poor people, at greater risk. Moreover, they must freely allow for the transfer of advanced energy efficient technologies to non-annex I countries and strengthen an appropriate financial mechanism to help meet the additional cost of emission stabilization/reduction for meaningful participation of developing countries.

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