Implications of Emissions Limitation Protocols and Concentration Stabilization Trajectories for Developing (Non-Annex I) Countries

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1. Introduction

The ultimate objective of the Framework Convention on Climate Change - FCCC (UNEP/WMO, 1992) is *stabilization of greenhouse gases concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.* The **concentration level** and the **time frame** for stabilization are two vital aspects affecting this objective. These are not explicitly specified in the FCCC, although the references to cost effectiveness, sustainable development, integration of climate change policies with national development programs etc. in the statement of principles (Article 3, FCCC) provide some guidance for deciding these issues. Evidently, to achieve any reasonable stabilization target, the global emissions will have to decline to levels far below the present emissions (IPCC, 1995; Wigley et al, 1996). A specified stabilization concentration level can be achieved by an infinite emissions trajectories. An aim of the climate change limitation agreement is to choose a concentration target and a corresponding emissions trajectory which is cost effective.

1.1 Emission Pathways for Concentration Stabilization

Climate change Modelling studies have examined different emissions trajectories to reach specified concentration levels (such as 550 ppmv of CO_2 equivalent). Studies such as by Richels and Edmonds (1996) have shown that selection of pathways to achieve a stabilization level is vital for cost effectiveness. Two well known sets of trajectories which are extensively discussed are those proposed by the Working Group I (WGI) of the Intergovernmental Panel on Climate Change - IPCC (Schmiel et al, 1995) and Wigley, Richels and Edmonds (Wigley et al, 1996) for the concentrations 350, 450, 550, 650 and 750 ppmv. IPCC trajectories for specified concentration levels are denoted as WGI350, WGI450, WGI550, WGI650 and WGI750 and WRE trajectories as WRE350, WRE450, WRE550, WRE650 and WRE750. In earlier research, the IPCC studies estimated emissions trajectories under future scenarios in a world without any climate mitigation effort. The six scenarios, known as IS92a to IS92f scenarios (Legget et al, 1992; Pepper et al, 1992; Alcamo et al, 1995) are used as benchmarks to assess the mitigation action under alternate pathways such as the WGI or WRE trajectories.

The WGI pathways were derived using constraints which exogenously specified the rate of change of concentration, target dates to achieve prescribed stabilization levels and a requirement that the implied emissions change smoothly. In addition, the WRE pathways assume that the emissions trajectory should initially track a “business as usual” path (Wigley et al, 1996). The WRE trajectories were constructed keeping in view the cost effectiveness criteria. These pathways were not derived from optimal cost models and hence are not claimed to be the most cost effective. It is however shown subsequently that the WRE pathways are very close to the most cost effective trajectories (Manne and Richels, 1997). Research has also demonstrated that the choice of alternate trajectories have significant climatic and economic implications (Richels et. al, 1996; Manne and Richels, 1996).

1.2 Emissions Limitation Protocols

A vital issue on the agenda of international negotiations on climate change is to decide the stabilization concentration level and a specific emissions trajectory to achieve this level at a prescribed future date together with the strategy to traverse this path. Various proposals are made by different countries or groups of countries (Table 1) for CO_2 or greenhouse gas emissions reduction targets by Annex I countries[1] for consideration under FCCC. These protocols are documented in the 31 January 1997 report of the Ad Hoc Group on the Berlin Mandate (AGBM) entitled “Framework Compilation of Proposals from Parties for the Elements of a Protocol or Another Legal Instrument” (FCCC/AGBM/1997/2, pp. 34-39). Each proposal is referred as a "protocol". Since a protocol is agreed at country level, the

[1] Annex I is the group of nations: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Czechoslovakia, Denmark, European Economic Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg,, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, Turkey, Ukranie, United Kingdom of Great Britain and Northeren Ireland, and the United States.

proposals can only specify emissions mitigation targets for nations. The resulting global emissions trajectory would lead to concentration levels in future which may be far from the desired level.

Since the FCCC calls for stabilization of greenhouse gas concentrations, the appropriate method to examine an emissions limitation protocol is to evaluate it vis-à-vis the desired emissions trajectory to reach the specified stabilization target. Any consistent protocol must track the chosen global aggregate emissions trajectory. Under the circumstance, an emissions limitations protocol for the Annex I nations would automatically determine the emissions trajectories for the Non-Annex I nations. Therefore, when a global emissions trajectory to achieve a target concentration level is prespecified, such as in case of WGI or WRE pathways, a protocol for Annex I nations automatically specifies the Non-Annex I emissions pathway.

This paper examines implications of global emissions pathway for concentration stabilization and the protocol limiting emissions of Annex I nations on Non-Annex I nations. While in the short run, the protocols for climate mitigation focus on Annex I nations alone, it is evident that in the long run substantial mitigation efforts will be needed in Non-Annex I nations to achieve the stabilization of concentration at reasonable levels, such as below the 750 ppmv. Moreover, the cost effectiveness would require participation of Non-Annex I nations as they may offer substantial low cost mitigation opportunities (Manne and Richels, 1996). Participation of Non-Annex I nations in a climate coalition will be guided not primarily by the global cost effectiveness of a mitigation strategy but by its implications on them.

1.3 Aim of the Paper

A major shortcoming of the climate change mitigation studies is that the results from the models are reported at highly aggregate levels and little regional or national level details are provided. Wide differences over model assumptions, representation of future social, economic and technological processes and the estimate of some crucial parameters continue to exist. In this respect, the contrast is stark between the Annex I and Non-Annex I nations due to their widely different levels of economic development. Very divergent priorities and preferences across these blocks of nations add to these differences. Since most models are developed in the Annex I nations, they tend to caricaturize the socioeconomic dynamics of Non-Annex I nations on the lines similar to those in the Annex I nations (Shukla, 1995; IPCC, 1996). As a result, the strategies proposed by the models tend to miss the vital differences among nations, regions and especially between industrialized nations (Annex I) and the developing world (Non-Annex I). A robust climate change agreement shall call for participation of all major constituents. The Non-Annex I nations are a very important block for the climate coalition. Understanding the implications of a protocol for Non-Annex I nations is therefore vital for building a robust coalition. The aim of this paper is to generate information and analysis which highlight the implications of proposed protocols for the Non-Annex I nations and help in arriving at a widely acceptable and implementable climate change agreement.

2. Emissions Scenarios and Protocols

The evaluation of an emissions limitation proposal requires comparison vis-à-vis a benchmark emissions scenario. We use IS92a, an intermediate IS92 scenario, as a benchmark. In all IPCC scenarios, including the IS92a, the Non-Annex I emissions grow rapidly and exceed those from the Annex I nations during the first half of the next century, in most cases within the next three decades. Since the growth rate of emissions and the structure of economies vary widely across the Annex I and Non-Annex I nations; the technologies, policies and measures to mitigate emissions in the nations across each group shall be very different.

2.1 Emissions Pathways

In the analysis, we consider three global emissions pathways corresponding to IS92a, WRE550 and WGI550 scenarios. The WRE and WGI scenarios, henceforth referred in the paper, are for the 550 ppmv concentration stabilization case. Choice of 550 concentration does not suggest any preference for that level for stabilization. This level is chosen since it is a medium case used for analysis in several studies. The analysis is for the period up to the year 2100, although the concentration may stabilize subsequently. Emissions trajectories for three scenarios are shown in Figure 1. It is important to note that although the WRE and WGI cases ultimately achieve identical concentration stabilization, their cumulative emissions vary substantially (Figure 2). The cumulative emissions for WRE550 are fifteen percent higher than the WGI550 case. A comparison of WGI and WRE emissions pathways with the IS92a emissions trajectories (Figures 1 and 2) suggests that achieving stabilization at 550 ppmv shall require substantial mitigation throughout the next century. The emissions thereafter will have to stabilize at a level far below the present emissions, for a global economy that will be many times larger that the present economy.

2.2 Protocols

From Table I, we consider only the Netherlands and the French protocols since these go up to the year 2100. Both protocols propose limitations only for Annex I nations. Two emissions trajectories are considered corresponding to the Netherlands protocol (N1 and N2) and one corresponding to French protocol (FM).

N1: Annex I stabilizes emissions in year 2000 to 1990 level and then reduces emissions at 1 percent annual rate.

N2: Annex I stabilizes emissions in year 2000 to 1990 level and then reduces emissions at 2 percent annual rate.

FM: This is a medium case for the French protocol with following assumptions. Annex I stabilizes emissions in year 2000 to 1990 level. Population growth is as per the central World Bank case (same as for IS92a). Per capita emissions in Annex I decline between years 2000 and 2010 to reach an average value of range of 7 and 10 percent reduction as proposed in

French protocol. Corresponding Annex I emissions in year 2010 is 4.341 GtC. French protocol proposes per capita emissions of 1.6 to 2.2 tC in year 2100. Emissions in year 2100 are obtained by taking mid value of proposed per capita emissions and population as per central World Bank case. Corresponding Annex I emissions in year 2100 is 2.690 GtC. Emissions trajectory from 2010 to 2100 is derived by a gradual decline in per capita emissions to reach the proposed 2100 target and population as per the central World Bank case.

Emissions trajectories for Annex I nations corresponding to the three protocols are shown in Figure 3. Corresponding cumulative emissions profiles for Annex I are shown in Figure 4.

2.3 Caveats and Clarifications

It is pertinent to spell out a few caveats and clarifications before embarking on the analysis of the emissions for the Non-Annex I nations. The Netherlands and French protocols are used in the paper just as illustration since these are already proposed. These protocols propose emissions limitations for Annex I nations. They do not refer to global stabilization target or emissions pathway or any emissions limitation for Non-Annex I nations. The emissions pathways for the Non-Annex I nations are derived in this paper by assuming that the Annex I nations shall follow a proposed protocol, while an stabilization agreement exists which will ensure the global emissions to follow WGI or WRE pathways. Rationally, a protocol to stabilize the concentration must follow an emissions pathway which leads to stabilization. Since the proposed protocols do not consider any stabilization pathway, the scenarios analyzed below are hypothetical. Nevertheless, the analysis is useful to understand the implications for the Non-Annex I nations of the protocols which would simultaneously propose the limitations on Annex I emissions and a global stabilization pathway.

Emissions trajectories for Non-Annex I countries are derived by subtracting the Annex I emissions for N1, N2 and FM protocols from WRE550 and WGI550 global emissions trajectories. These trajectories are neither claimed to be cost effective nor do they correspond to actual Non-Annex I emissions in the original WRE or WGI 550 cases. As stated, the analysis presumes that the global emissions will follow a WRE or a WGI emissions pathway for stabilization at 550 ppmv concentration level and the Annex I nations will follow one of the N1, N2 or FM protocols. Then, the balance emissions shall be from the Non-Annex nations.

An important clarification is in order regarding the interpretation of Annex I and Non-Annex I emissions trajectories. These are not necessarily the target emissions to be followed by each block, but can be interpreted as emissions quotas for each block. The emissions trade across the two blocks (or even within the blocks) and programs like activities implemented jointly (AIJ) can be used to arrive at the most cost effective global strategy. In this sense, any distribution of emissions pathways between Annex I and Non-Annex I nations can be made equally cost effective for an identical global emissions pathway. The different emissions allocations however will have varying equity implications in terms of wealth transfer between the two blocks. In computing the growth rates (Tables 2 to 5), emissions pathway for each block is treated as an independent target. This is intended merely to highlight the differential rates of emissions growth and the decline in emissions intensity across the two blocks. In reality, the blocks will trade emissions for cost effectiveness. The actual emissions trajectory for each block shall therefore turn out to be different than that proposed by the protocol.

3. Non-Annex I Emissions Pathways

Emissions pathways and cumulative emissions for the Non-Annex I nations corresponding to a combination of a WRE or a WGI scenario with a N1, N2 or a FM protocol are shown in Figures 5 and 6. The Non-Annex I emissions in the year 2100 range from 3.97 (WRE with FM scenario) to 6.58 (S with N2 scenario) GtC. The emission in the year 2100 for the IS92a case is 13.41 GtC. Thus, depending on what protocol Annex I nations follow, the Non-Annex I nations will have to reduce their emissions by a half or to below a seventy percent of the IS92a emissions in the year 2100 (Figure 7). Corresponding cumulative emissions of Non-

Annex I nations for the period 1990 to 2100 range from 408 (S with FM scenario) to 695 (WRE with N2 scenario) GtC compared to 785 GtC for IS92a scenario. Since WRE scenarios permit high initial emissions, the emissions during later periods need to decline sharply in comparison with a corresponding WGI scenario. Cumulative emissions in WRE scenarios are much higher compared to corresponding WGI scenarios (Figure 6). Therefore, the WGI scenarios need greater cumulative mitigation than a comparative WRE scenario (Figure 8). Each protocol calls for a sharp decline in emissions from Annex I nations relative to the IS92a scenario throughout the next century (Figures 9 and 10).

4. Implications of Protocols and Stabilization Pathways

Growth of emissions in Non-Annex I under WRE and WGI scenarios follow very different patterns (Tables 2 and 3). In WRE scenarios, for the period 1990 to 2025, emissions initially grow very rapidly. For Non-Annex I, the WRE emissions can grow at rates (range 3.6 to 4.24 percent) which are even higher than that for IS92a non-intervention scenario. In case of WGI scenarios, the emissions grow at much slower pace during initial decades compared to IS92a. For the Annex I nations following the protocols (Table 3), emissions start to decline from year 2000. In contrast, in IS92a scenario, the Annex I emissions grow during this period at a rate of 0.81 percent. For WRE scenarios, the carbon intensity (carbon emission per GDP) in Non-Annex I nations needs to decline only marginally (range 0.46 to 1.10 percent) during this period (Table 4). The autonomous energy efficiency improvements alone shall be adequate to attain such a decline. The WGI scenarios on the other hand would require a rapid and early improvement of carbon intensity in Non-Annex I nations (ranging from 1.96 to 3.09 percent annually for the period 1990-2025). This shall require implementing early mitigation actions, beyond the autonomous improvements in energy efficiency and decarbonization.

Emissions growth and carbon intensities should decline substantially during the second quarter of next century in case of WRE scenarios. In that period, the emissions growth rate in Non-Annex I nations needs to remain below half a percent and carbon intensity must decline at a rate of around 2.5 percent. This will happen only if substantial technological change is instituted which will improve energy efficiency as well as decarbonize the energy supply. During the later half of next century, the rate of carbon intensity improvement required for WRE scenarios is even more steep and reaches nearly 4 percent annually during the last quarter of next century. WGI scenarios require lower carbon intensity improvement during 2025-2075 period. Thereafter, in the last quarter of next century, the carbon intensity improvement required under the WGI scenario (over 3.5 percent) is comparable to WRE scenario.

Following are some observations from the analysis of emissions pathways for WRE and WGI scenarios with different protocols.

4.1 WRE Scenarios

WRE emissions pathway does not require major policy initiatives during the next three decades for mitigation beyond the IS92a case. If Annex I follows any emissions limitation protocol, then the Non-Annex I emissions may continue to exceed IS92a levels in this period and in 2050 the Non-Annex I emissions can reach 3 to 4 times the emissions in 1990 (Figure 5). The emissions in 2015 shall exceed IS92a emissions by 40 to 65 percent (Figure 7). Typically, these trajectories imply that the Non-Annex I countries with own coal resources, such as China and India, can continue to fuel the economic growth using coal during the next three decades. Thereafter, under the WRE scenarios, major technological transition is needed which must simultaneously improve energy efficiency and decarbonize energy supply very rapidly till the end of the century. Countries which by that time would have committed investment on coal mines and coal based energy system would find this rapid transition very difficult to adjust to, not only economically but more so socially and politically since the coal regions are among the poorest in many countries.

4.2 Technological Progress for Optimal and WRE Emissions Pathways

The least cost emissions pathways derived by using the MiniCAM model (Edmonds et al, 1997) suggest that the optimal costs and emissions pathways are very close to those for the WRE case. The WRE trajectories are not derived using any cost effectiveness analysis. Yet, since the WRE emissions pathways are close to the optimal emissions pathways, they will require the level of technological change similar to that for the optimal case. The optimal cost studies make crucial assumptions[2] about the rate of energy efficiency improvement and the availability of non-fossil backstop technology at a competitive price. These assumptions play vital role in arriving at the emissions pathways. The assumptions for the Annex I nations, such as the improvement in fossil power plant efficiency at an annual rate of 1 percent from 1990 to 2050 or the end-use efficiency improvement in Eastern Europe and Soviet Union at a rate of 2.5 percent during the period would by themselves require considerable policy initiatives. The assumption in the optimal cost study using MiniCAM model that the price of non-fossil energy technologies (except hydro and nuclear) will decline at 4.5 percent rate annually till 2025 will materialize only under considerable Research and Development initiative. Similarly, assumption about availability of biomass energy at a price that declines at 1 percent rate would realize only if policy initiatives are instituted in plant genetics, plantation practices and conversion technologies. In absence of early market penetration of these technologies, it is presumptuous to anticipate the market to have perfect foresight to induce technology development at such high rates. Besides, restricted land supply may limit the penetration of biomass technologies.

Although the WRE scenarios do not require early mitigation, they do call for preparedness through technology innovations and institutional capabilities. The technological change required in Non-Annex I countries after the second quarter of the next century seems hard to attain unless major policies, institutions and capacity building for successful technology transfer are created during next few decades. The assumptions of rapid energy efficiency improvements and availability of backstop technologies also need very careful assessment

[2] Aurthor gratefully acknowledges the information provided by Dr. Jae Edmonds on these assumptions

since if these do not materialize, the rapid transition to a lower emissions trajectory shall be unlikely. Following a WRE trajectory involves considerable risk since the mitigation actions are delayed and are drastic during the later periods. Although the WRE scenario do not call for any major bifurcation in development (or even technological) patterns, the opportunities for bifurcation which may lead to lower emissions may arise in many Non-Annex I nations and these should not be missed. It would be advisable to devise contingency plans, if WRE pathways are to be followed, to respond to any drastic actions which may be needed later on. Such rapid response strategies need serious consideration especially in view of the apprehensions raised by Grubb et al (1995), Chapius et al (1996), Grubb (1996; 1997), Ha Duong, et al (1996) and Shukla (1996b) against the desirability of WRE proposals on different grounds such as the influence of uncertainties, technological inertia, endogenous nature of technology evolution and myriad problems with technological transitions in developing countries.

4.3 WGI Scenarios

Emissions pathways for WGI scenarios require rapid decline in global emissions starting immediately. Under the WGI550 scenario, unless Annex I nations start reducing their emissions immediately at an annual rate above 2 percent, the Non-Annex I nations will have to start immediate drastic mitigation (Figure 6). This will require major changes in infrastructure, energy technologies and energy supply mix. Some inefficient and carbon intensive capital stock may have to be retired early. Such transformation is unlikely to be attained following the conventional development pattern. During the next half century, most Non-Annex I nations shall experience a rapid economic growth and will make major investments in infrastructure, energy resources development and technologies. This will provide a “window of opportunity” (Perez and Soete, 1988) to the developing nations to leapfrog industrialized nations in efficient technologies and low resource intensive development. Market forces alone can not orient the economy along such a development pattern. A strategic combination of strong policy regime, appropriate institutions and efficient instruments will be vital to reorient the development pattern along an energy efficient and low carbon intensive trajectory. Major opportunities will exist in areas like infrastructure and urban planning (Hourcade, 1993), energy technologies and education which may alter the consumption behavior and population growth.

Under WGI scenarios, the Non-Annex I nations must participate strongly in the emissions mitigation immediately. Unless the Annex I nations accept strong mitigation protocols (such as N2 or Denmark protocol), the carbon intensity in Non-Annex I nations shall be required to decline at a very high rate of 3 percent annually in the immediate future. Instant realization of such a high rate of improvement in carbon intensity in Non-Annex I nations seems very unlikely. For instance in India, the carbon intensity under the non-intervention scenario is expected to decline by 1.5 percent over next forty years (Shukla, 1996a). Sustained decline in carbon intensity for next forty years at a 2.5 percent annual rate shall cause a GDP loss of over three percent (Fisher-Vanden et al, 1997). Besides, such intensive mitigation effort will change significantly the cost structure of energy intensive commodities like steel and aluminum, where major investments are recently made and more are expected in coming decades (Shukla, 1996b). The competitive disadvantage to these industries will add to economic pressures and can be expected to generate intense resistance against mitigation.

After an immediate and high rate of decline in carbon intensity in the Non-Annex I nations during the next three decades, the WGI scenarios require a very moderate decline (around 1.3 percent annual rate) during the second quarter of the next century (Table 4). Then again, during the second half of next century, the carbon intensity needs to decline very rapidly at rates close to those for the WRE scenarios. After a strong initial mitigation efforts, a sudden relaxation during the next quarter seems to be unwise to follow, unless major improvements were available initially from cheap or “no regret” actions which are exhausted during the next few decades. However despite the technological optimism over the harvesting of low cost and “no regret” options such as energy efficient technologies, the penetration of these technologies in developing countries has remained low and the “no regret” options have proved to be elusive (Shukla, 1997). Following the WGI emissions pathway therefore shall impose substantial mitigation costs in Non-Annex I nations during next few decades. This strategy is neither cost effective (Richels and Edmonds, 1996) in the long run nor it will be politically feasible. Also, WGI strategy of losing the momentum of technological change built in the first quarter during the second quarter and again picking up the momentum later on is unrealistic and may prove to be expensive. The cost effectiveness and political feasibility shall require a lower mitigation target initially and enhanced mitigation later on. A compromise emissions trajectory which lies between WGI and WRE pathways may be appropriate. Such a trajectory will be cost effective compared to WGI pathway and less risk prone than the WRE pathway.

4.4 Implications of Protocols

Evidently, the protocols followed by the Annex I nations have direct implications for the Non-Annex I nations for a chosen stabilization concentration. The emissions pathway as per the N2 trajectory requires a strong mitigation commitments for Annex I nations. This protocol therefore eases the cumulative mitigation burden on Non-Annex I nations over the next century by 165 GtC (Figures 4 and 6) compared to FM protocol. A strong Annex I emissions limitation protocol shall allow the Non-Annex I nations to make a gradual transition towards lower carbon intensity during the next century. This is especially crucial during the initial decades if the global emissions are to follow the WGI pathway which requires substantial immediate mitigation. Contrarily, for WRE scenario, the mitigation commitment by Annex I nations needs to be stronger in the long run (i.e. after 2030). The analysis of stabilization pathways makes it abundantly clear that considerable mitigation must happen during the next century. This calls for a strong global protocol. The concentration is essentially a stock problem. High mitigation commitment during the next century from the Annex I nations is not only historically justified, but is necessary to lessen the burden of mitigation on Non-Annex I nations whose primary agenda during the next century shall be their economic development.

5. Issues of Transparency, Disaggregation and Implementation

The results from the integrated global modelling studies are reported at highly aggregated levels. The models and the studies are actually designed to deal with issues at aggregate levels. The pathways generated by these models, such as WRE, Optimal Cost and WGI pathways, are specified at global level. Regional, sectoral and technology details associated with these aggregated results are not readily made available. Besides, the models have embedded assumptions which are vital to the results but are nor adequately justified or validated. As a result, the rationality and practicality of these trajectories can not be readily ascertained. For instance, the details of assumptions and results for Non-Annex I nations are especially important to assess the practicality of WRE (or Optimal cost) pathways since major cost savings are expected to arise not from the timing (i.e. when aspect) but from the location (i.e. where aspect) of mitigation actions, which are substantively located in Non-Annex I nations (Manne and Richels, 1996; Richels et al, 1996). In absence of details, the results lose utility for policy making since the expected aggregate gains may fail to materialize if each component can not be reproduced. Furthermore, in absence of information on timing and rates of penetration of future technologies, the practicality and implementability of results can not be confirmed.

Although well known, it is pertinent to repeat that the model results are a package deal and the entire package in every detail needs to be reproduced for gains to be realized. The aggregate trajectories can be achieved through an infinite sets of actions derived from multifarious combination of actions at detailed levels. Even if the model assumptions are realistic, the cost effectiveness can be achieved only when the optimal package is possible to be reproduced in every detail in reality. The WRE (or Optimal Cost) trajectories are cost effective under presumed conditions. Their acceptance for policy making requires the results to be accepted not for their rationality within the presumed world, but for their practicality at regional and sectoral levels within the real world. On the contrary, the WGI pathways seem unrealistic since the immediate and high mitigation commitments needed are unimplementable and politically infeasible. The issues of implementability and transparency are especially vital for developing countries where the reality may be far different than the model assumptions (Shukla, 1997).

6. Conclusions

The stabilization of greenhouse gases concentration in the atmosphere at any reasonable level shall require substantial mitigation effort during the next century. The costs of mitigation during the next century will aggregate to several trillion US dollars at current prices. Although the proposed protocols specify the mitigation commitments for the Annex I nations alone, they implicitly determine the Non-Annex I emissions trajectories for a chosen stabilization concentration and a corresponding emissions pathway. The analysis in this paper considered two well known emission trajectories (WGI and WRE) and three protocols (Two extremes of Netherlands proposal and a medium case of French proposal).

WRE and WGI propose vastly different global emissions pathways. These translate into very different emissions trajectories for the Non-Annex I nations, for any protocol followed by the Annex I nations. WRE scenarios require very little mitigation during first three decades, but a very steep decline in carbon intensity during the rest of next century. WRE pathway is cost effective, unlike WGI pathway which has substantially more mitigation costs. Although, WRE scenarios are cost effective, they pose greater risk since the mitigation actions are delayed. The cost effectiveness of a WRE pathway vis-à-vis a WGI pathway is partly factored in by a high discount rate (5 percent) as well as strong assumptions on exogenous technological change which ignore the importance of learning and endogenous nature of technological change (Grubb, 1997). Emissions pathways with trajectories that lie between the WRE and WGI pathways may be explored to overcome weaknesses of either trajectories.

The stabilization objective declared in the UNFCCC requires agreeing to a global emissions pathway. The cost effectiveness of a global emissions pathway, such as claimed by WRE, will materialize through mitigation programs implemented globally and in unison. The cost effectiveness will require high rates of mitigation in Non-Annex I nations. This can be achieved only if strategies, processes, institutions and instruments are created whereby Annex I nations shall make commitments for technology transfer, joint implementation of mitigation activities, financial transfers to alleviate the welfare losses in Non-Annex I nations arising from mitigation actions and show readiness to commit additional resources (and finances as insurance cover) in case of policy failures or occurrence of extreme events.

Affirming the principle of historical justice, the FCCC advocates differentiated mitigation commitments wherein "*developed country Parties should take lead in combating climate change and adverse effects thereof*". To be cost effective, the emissions limitations agreed under a protocol by the Annex I nations should not to be treated as targets to be achieved by the Annex I nations alone. Realizing this, FCCC exhorts "*developed countries to take immediate action in a flexible manner*". Cost effectiveness requires that the emissions limitation proposed by a protocol for the Annex I nations can be treated as a mitigation quota which can be traded against mitigation elsewhere through bilateral or multilateral agreement. In such an arrangement, the developed countries shall have the incentive for innovations of mitigation technologies, which can be transferred to developing countries on mutually agreed terms. The participation of Non-Annex I parties in emissions limitation may be decided based on widely agreed equity principle. The emissions allocation principles such a per capita, per GDP, agreed baseline (such as business-as-usual) or historical (grandfathered) emissions have strong pros and cons which would restrict their wide acceptance. A plausible equity principle for each Non-Annex I nation to join the emissions limitation would be at a future date when per capita income (valued at purchasing power parity) of the nation would equal the average income of Annex I nations when they accept their mitigation commitments. Till then the mitigation actions in Non-Annex nations may have to be offset through AIJ or traded.

The Non-Annex I nations enter the 21st century facing many vital challenges. Climate change is one such challenge, but not the most urgent concern on their agenda. The most crucial challenge before these nations during the next century is the human development. To the extent the climate change actions tie in with the development policies, it would be possible to synergistically manage both the challenges. The excessive mitigation targets for Non-Annex I nations shall affect economic development and will be resisted. At the same time, a higher rate of economic growth in the Non-Annex I nations shall allow a rapid replacement of inefficient technology stock and and opportunity to leapfrog developed countries in energy efficient and low carbon technologies. This possibility can be translated into substantive mitigation opportunities at low cost. A cost effective and robust emissions mitigation protocol should go beyond proposing the emissions targets and should include the strategy of achieving these targets as a unified package. The protocol should propose mechanisms for co-operation among nations and especially across Annex I and Non-Annex I nations which shall be critical to achieve the technological transitions in developing nations to cost effectively meet the global commitments agreed by the parties to the protocol.

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Table 1: Description of Proposed Protocols for Annex I Countries (All reductions are relative to the 1990 level)

1. AOSIS	Reduce CO_2 emissions by at least 20% by 2005.
2. Austria Germany	Reduce CO_2 emissions by 10% by 2005, and by 15-20% by . 2010
3. Belgium	Reduce CO_2 emissions by 10-20% by 2010
4. Denmark	Reduce CO_2 emissions by 20% b 2005, and by 50% by 2030
5. Switzerland	Reduce ghg emissions by 10% by 2010
6. U.K	Reduce ghg emissions by 5-10% by 2010
7. Zaire	Reduce ghg emissions to 1990 level by 2000, reduce emissions by 10% by 2005, by 15% by 2010, and by 20% by 2020
8. Netherlands	Reduce ghg emissions by an average of 1-2% per year (from 2000, see item 10 below)
9. France:	Reduce per capita ghg emissions by 7-10% over 2000-2010 Reduce per capita ghg emissions to 1.6-2.2 GtC/bn by 2100
10. E.U:	Return ghg emissions to 1990 by 2000. (Applies, in addition, specifically to proposals by countries 2,3,4,8 and 9)

NOTE: Some proposals apply to CO_2 alone, others to CO_2 plus other greenhouse gases (ghg) presumably in some equivalent CO_2 emissions sense. The E.U. proposal refers specifically to greenhouse gases not covered by the Montreal Protocol

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Table 2: Emissions Growth Rate (%) for Non-Annex I Nations

	IS92a	WRE & N1	WRE & N2	WRE & FM	WGI & N1	WGI & N2	WGI & FM
1990-2025	3.29	3.89	4.24	3.60	2.14	2.74	1.61
2025-2050	1.80	0.46	0.57	0.31	1.68	1.62	1.67
2050-2075	1.18	-0.40	-0.32	-0.55	0.89	0.78	0.97
2075-2100	0.97	-0.85	-0.76	-1.11	-0.60	-0.55	-0.79
1990-2100	1.94	1.04	1.21	0.82	1.12	1.28	0.93

Table 3: Emissions Growth Rate (%) for Annex I Nations

	IS92a	N1	N2	FM
1990-2025	0.81	-0.72	-1.43	-0.28
2025-2050	0.03	-1.00	-2.00	-0.48
2050-2075	0.02	-1.00	-2.00	-0.58
2075-2100	0.54	-1.00	-2.00	-0.52
1990-2100	0.39	-0.91	-1.82	-0.45

Table 4: Carbon Intensity Improvement (%) for Non-Annex I Nations

	IS92a	WRE & N1	WRE & N2	WRE & FM	WGI & N1	WGI & N2	WGI & FM
1990-2025	1.41	0.81	0.46	1.10	2.56	1.96	3.09
2025-2050	1.15	2.49	2.38	2.64	1.27	1.33	1.28
2050-2075	1.77	3.35	3.27	3.50	2.06	2.17	1.98
2075-2100	1.98	3.80	3.71	4.06	3.55	3.50	3.74
1990-2100	1.66	2.56	2.39	2.78	2.48	2.32	2.67

Table 5: Carbon Intensity Improvement (%) for Annex I Nations

	IS92a	N1	N2	FM
1990-2025	1.61	3.14	3.85	2.70
2025-2050	1.24	2.27	3.27	1.75
2050-2075	1.25	2.27	3.27	1.85
2075-2100	0.73	2.27	3.27	1.79

1990-2100	1.28	2.58	3.49	2.12

Figure 1: Global Emissions Trajectories

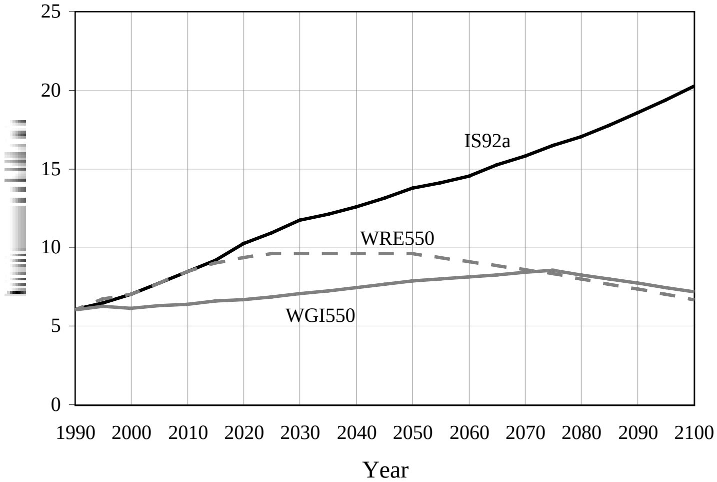


Figure 2: Global Cumulative Emissions Trajectories

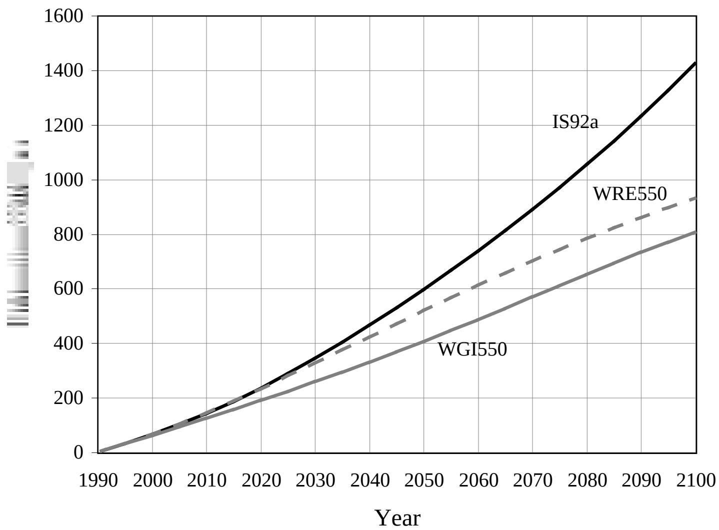
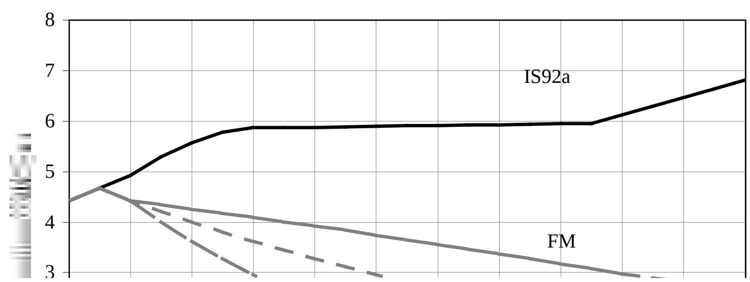


Figure 3: Annex I Emission Trajectories under Different Protocols



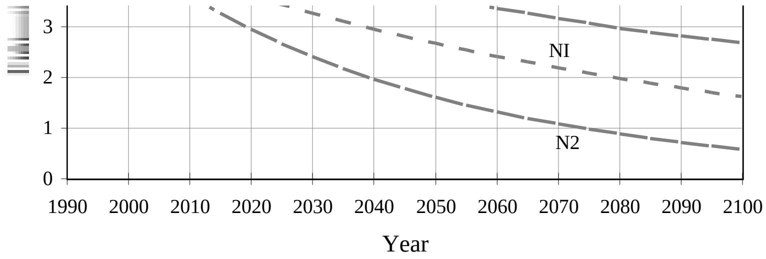


Figure 4: Annex I Cumulative Emission Trajectories under Different Protocols

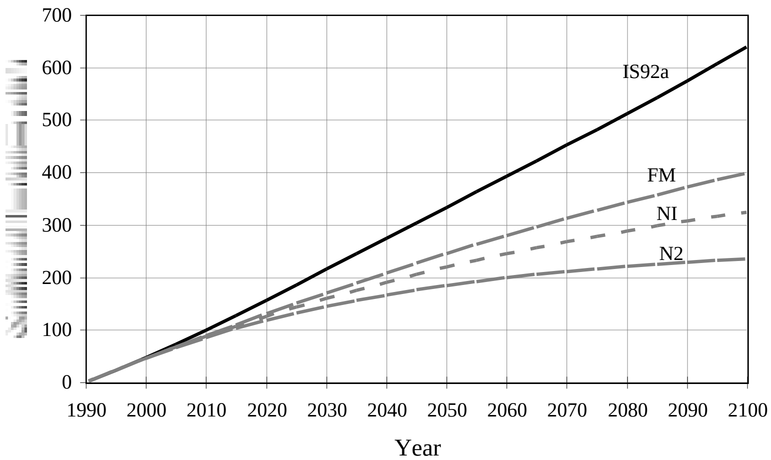


Figure 9: Percent of IS92a Emissions (Annex I)

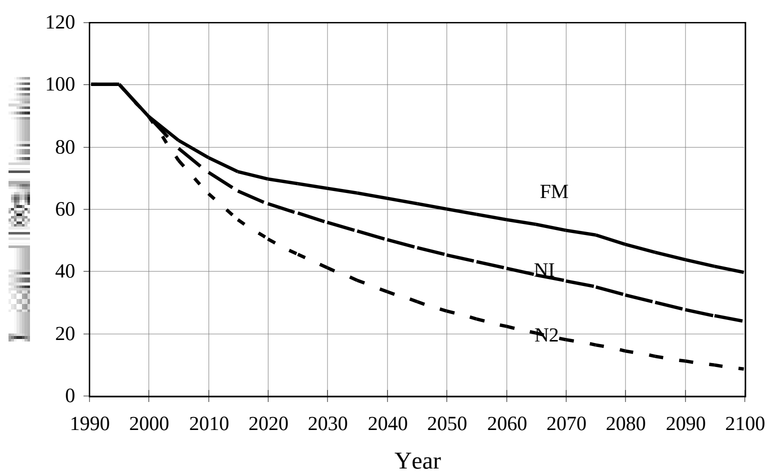


Figure 10: Percent of IS92a Cumulative Emissions (Annex I)

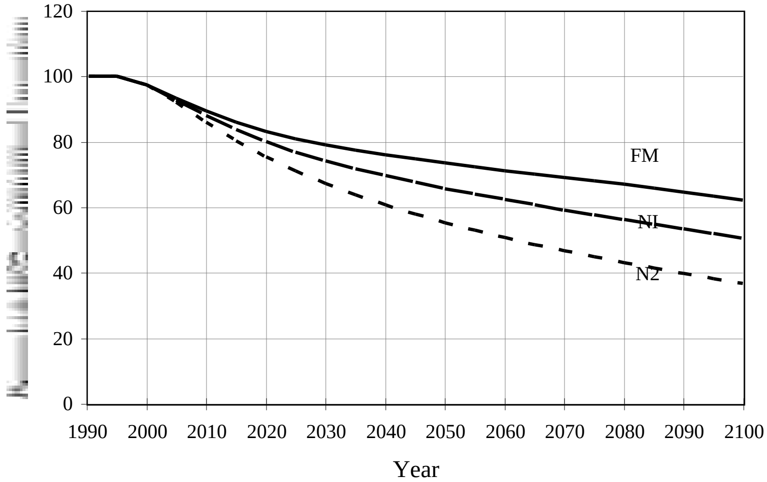

120
100
80
60
40
20
0
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
FM
NI
N2

Figure 5: Non-Annex I Emissions under Different Scenarios

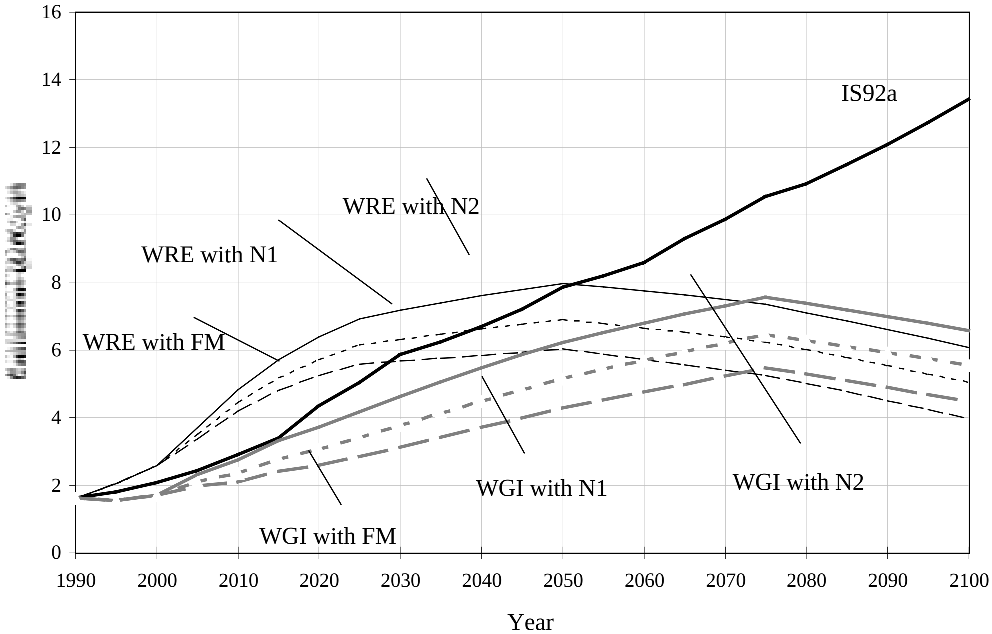


Figure 6: Non-Annex I Cumulative Emissions under Different Scenarios

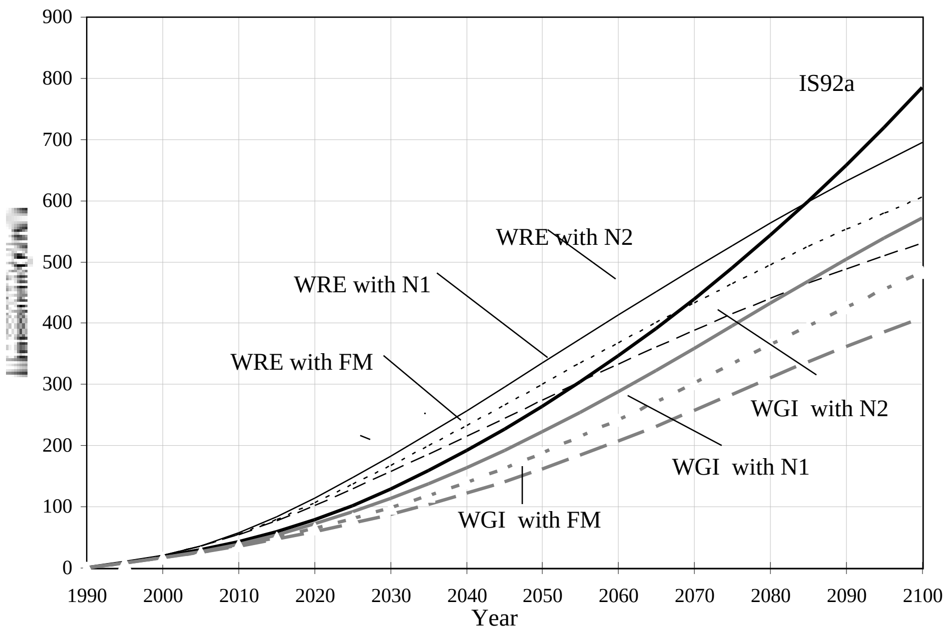


Figure 7: Percent of IS92a Emissions (Non-Annex I)

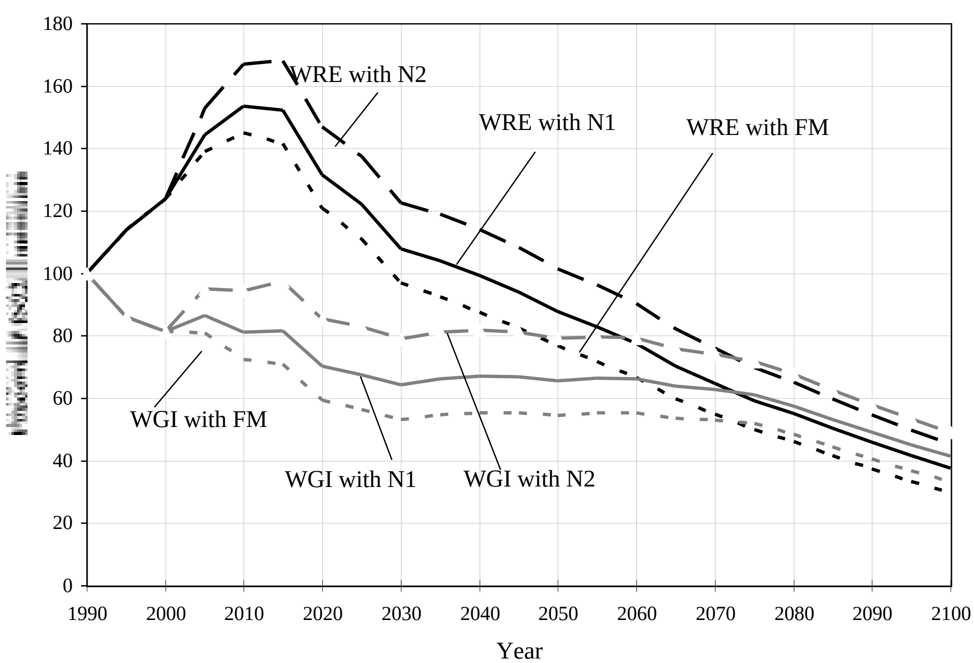


Figure 8: Percent of IS92a Cumulative Emissions (Non-Annex I)