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Towards an equitable global climate change regime: compatibility with Article 2 of the Climate Change Convention and the link with sustainable development

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Abstract

In this paper we argue that the discussion on how to get to an equitable global climate change regime requires a long-term context. Some key dimensions of this discussion are responsibility, capability and development needs. Each of these, separately or in combination, has been used in designing schemes for differentiation of commitments to limit or reduce greenhouse gas emissions. Many implementation problems of these proposals are often side-stepped. In particular, some proposals may be incompatible with Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC), i.e. they are unlikely to keep the option open of long-term stabilisation of atmospheric greenhouse gas concentrations at relatively low levels. We present some evidence that shifting the emphasis from emission reduction to sustainable development needs can contribute significantly to relieving the threat of human-induced climate change.

Keywords: Climate policy; Climate regimes; Equity; Differentiation of commitments; Burden sharing; Sustainable development

1. Introduction

Climate change is a global problem. However, there are large differences in emissions of greenhouse gases between countries. The patterns of emissions in the past will be different from those in the future. Wherever greenhouse gases are emitted, the negative impacts from rising greenhouse gas concentrations such as threats to food production, ecosystems and human settlements will be unevenly distributed. Developing countries are much more vulnerable than industrialised countries due to their larger dependence on agriculture, limited infrastructure, lack of knowledge and technology and their limited financial,

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institutional and governance capabilities (IPCC, 2001a). These climate change impacts can seriously undermine the prospects for sustainable development.

The driving forces for greenhouse gas emissions: population, economic growth, land use and the choice of technology, are intricately linked to development. The development patterns of current industrialised countries have caused most of the current change in the climate; its future change will largely be determined by the development patterns of the currently less industrialised countries. Greenhouse gas emission projections for the next 100 years show a range from below present levels to a four-fold increase. However, keeping climate change under control would require a reduction to less than 50% of current levels in the longer term (IPCC, 2001b).

These are the ingredients for a politically very sensitive and controversial debate on how to distribute efforts in an equitable way to realise such reductions and realise the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) to avoid dangerous interference with the climate system? Would connecting this debate to the quest for sustainable development help us to find politically acceptable solutions to the climate problem? These questions are explored in this paper.

2. The current differentiation of commitments

The UNFCCC contains a number of key notions and principles that are providing guidance on how to handle the distribution of emission reduction efforts. It makes reference to sustainable development, equity and "common but differentiated responsibilities and respective capabilities" (UNFCCC, 1992). These principles and considerations are also reflected in current academic thinking on equity and fairness principles (see Banuri et al., 1996; Rose et al., 1998; Toth et al., 2001). The most substantive principles in distributing efforts are the following (Ringius et al., 2002).

- *Responsibility*: Mitigation efforts (or emission allowances) should be proportional to the contribution to the problem.
- *Capability*: Mitigation efforts should be proportional to the capability to contribute, i.e. depend on income, technology, institutions and natural resources.
- *Need*: Mitigation efforts or emission ceilings should leave room to eradicate poverty and to attain a reasonable standard of living or, in other words, should respect the (equal) right of humans to develop.

2.1. Responsibility

The change in climate observed today has been caused by past emissions of various greenhouse gas emissions from energy use and land-use change. Two-thirds of the increase in atmospheric greenhouse gases over the past 150 years stems from the presently industrialised countries (den Elzen et al., 1999). Their share in current emissions is also still over half. Despite an expected rapid rise in the greenhouse gas emissions of currently less industrialised regions—probably surpassing those of the industrialised regions in the coming decades—the contribution of the industrialised regions to the rise in concentration will remain high for quite a while because of the relatively long lifetime of most gases. Fig. 1 shows the relative contribution of Annex I and non-Annex I countries for climate change related indicators. Obviously, it matters which indicator is chosen in assigning responsibility.

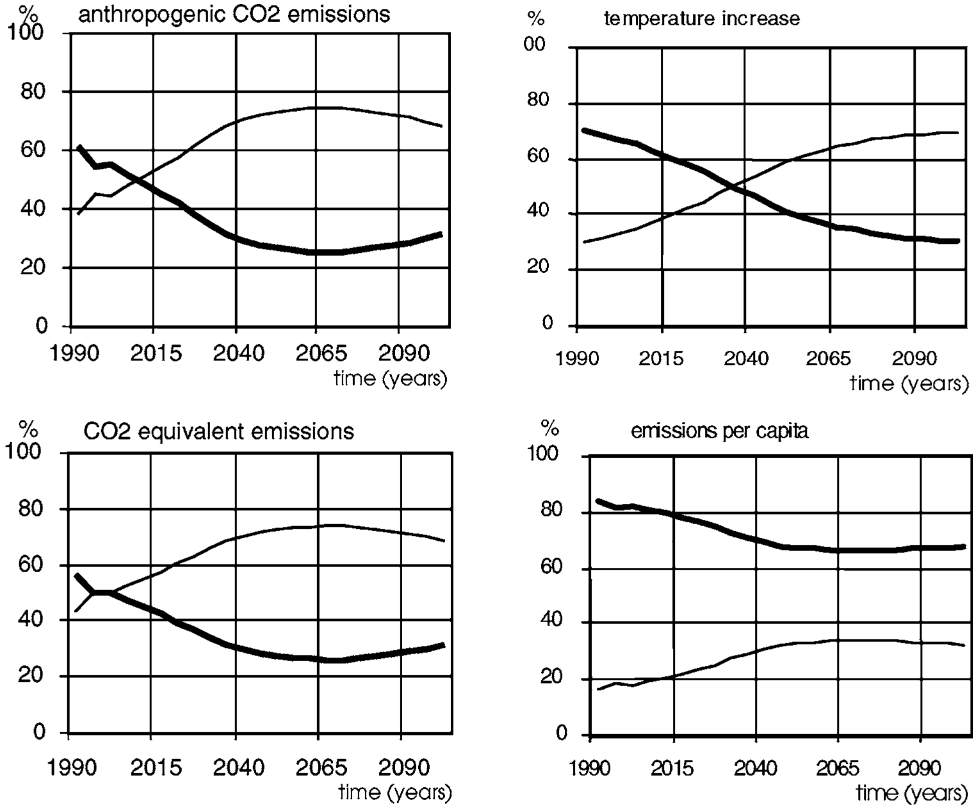

Fig. 1. Contribution of Annex I (darker lines) and non-Annex I (lighter lines) to various indicators of climate change on the basis of the IMAGE SRES A1 scenario (den Elzen et al., 2001). Source: FAIR model (den Elzen et al., 2001). Note: the left-hand column shows the contribution to anthropogenic CO_2 emissions (top) and anthropogenic CO_2 equivalent emissions (bottom); the right-hand column shows the contribution to temperature increase (top) and CO_2 emissions per capita (bottom).

2.2. Capability

There is a large difference in developed and developing countries' capabilities to adapt to and mitigate climate change (Yohe, 2001). Even between industrialised countries there are large differences in income, economic structure and national circumstances. Some countries can build dikes to protect themselves against sea level rise; others cannot afford this. Some have access to large hydropower resources, others depend almost fully on fossil fuels. Mitigation capabilities are not identical to opportunities: while there may be many opportunities for relatively cost-effective abatement measures in a country, its actual capability to take these measures may be severely limited due to technological, institutional and financial constraints. Capability, here, refers to countries' ability to pay as well as to their mitigation opportunities.

2.3. Need

Development does require energy and will lead to changes in land use. Given the current gaps in development levels, this will inevitably lead to additional emissions of greenhouse gases for developing countries (Nakicenovic et al., 2000). The UNFCCC makes it clear that combating climate change should not hinder sustainable development. This is based on the notion that, as part of human rights, all humans have an equal right to development. Furthermore, the impacts of climate change should not hinder development needs either. The challenge is to combine development objectives with emission reductions and adapting to climate change. This means that the distribution of climate change impacts and adaptation efforts needs to be taken into account (Metz, 2000).

2.4. Application in the Climate Change Convention (UNFCCC)

The UNFCCC has translated the above mentioned equity principles by dividing countries into two categories: first, Annex I countries (industrialised countries in OECD and eastern Europe/former Soviet Union); second, non-Annex I countries (all others, mostly called developing countries, although including OECD member countries, Mexico and Korea, and relatively high income countries like Singapore, Argentina and Saudi Arabia (World Bank, 2000)). The UNFCCC states that Annex I "... should take the lead ..." (Article 3.1) and "... should adopt policies and measures with the aim of returning their greenhouse gas emissions to 1990 levels by 2000" (Article 4.2). However, the legally ambiguous wording has prevented this commitment from being binding. Non-Annex I countries have obligations to prepare inventories of greenhouse gas emissions and general obligations to minimise emissions where possible (Article 4.1), provided assistance is available and poverty eradication is not threatened (Article 4.7). OECD countries have obligations to assist developing countries with technology and financing in pursuing those objectives (Article 4.5).

2.5. Application in the Kyoto Protocol

The Kyoto Protocol (KP; UNFCCC, 1998) keeps this division of countries intact. When the mandate for negotiating the protocol was agreed by the Parties to the Convention in 1995, developing countries insisted not to include new commitments for them above those already covered by the Convention. Their argument was: the Convention has no legally binding obligations for Annex I to reduce emissions and therefore, real reductions through the Protocol should first be realised before discussing additional commitments for developing countries. And indeed, by now it is clear that only a few Annex I countries have managed to reduce their emissions to below 1990 levels. In most countries emissions have increased (UNFCCC, 2001). The KP should now turn this around with its legally binding emission limitations. It also contains the so-called clean development mechanism (CDM) that gives the opportunity to industrialised countries to realise emission reductions through projects in developing countries, which could be an important contribution towards shifting development in developing countries into a more sustainable direction.

Within the group of industrialised countries an equitable differentiation of emission reduction obligations had to be agreed. Lengthy debates on principles and multiple proposals on a systematic approach for such a differentiation did not result in a rational outcome (Depledge, 2000). In the end, a strictly political deal was made with special treatment of certain countries. Within the European Union (EU) the common reduction target in the Protocol had to be distributed amongst its member states. After many years of internal negotiation the EU reached agreement on the approach just before the Kyoto meeting and finalised that agreement in 1998. The principles of fairness discussed above also played a prominent role in the EU. So, it was not an economic criterion of marginal abatement costs, but rather differences in level of development ("need"), national energy systems and industrial performance ("capability/opportunity") and emissions per capita ("responsibility") that determined the differentiation in the EU (Phylipsen et al., 1998) (see also Triptych approach below). It provides an interesting example how to deal with differentiation amongst countries differing widely in energy and economic characteristics.

3. Proposals for moving towards a global climate change regime

Both prior to the negotiations on the KP and afterwards there have been many proposals for differentiating mitigation commitments among countries, both from academic circles as well as from Parties to the UNFCCC (see Banuri et al., 1996; Reiner and Jacoby, 1997; Ringius et al., 1998; Depledge, 2000). We will use the typology of main equity principles presented above to order and discuss a selection of the wide range of options identified. Some proposals are based on several principles.

3.1. Focus on responsibility

One proposal for differentiating commitments specifically based on the responsibility principle is the so-called Brazilian proposal. In its proposal, made during the negotiations on the KP, Brazil suggested to differentiate Annex I commitments on the basis of their relative contribution to realised temperature change (UNFCCC, 1997). By taking an indicator late in the cause–effect chain the proposal accounts for the large historical contributions of developed countries to the climate problem. den Elzen et al. (1999) developed a global application of the Brazilian approach. In order to avoid all developing countries having to contribute to global emission control immediately, they suggested to combine the approach with the use of a threshold for participation. In addition, they suggested a per capita approach (per capita contribution to global warming as basis for determining responsibility) rather than total contributions.

3.2. Focus on capability

One example of a climate regime based on the principle of capability it that of Jacoby et al. (1999). They propose an architecture that uses welfare (measured by per capita income) both as a trigger for participation as well as for differentiating commitments amongst countries, while the stringency of commitments is determined by the overall reduction rate required to meet a specific stabilisation level.

Another salient set of proposals in the discussion on possible commitments for developing countries has been related to the idea of intensity targets (see Hargrave, 1998; Baumert et al., 1999; Philibert, 2000). Recently, the concept has also been embraced by the Bush administration as a US alternative to the fixed target approach adopted under the KP (White House, 2002). Such targets would not set absolute, but relative emission limits, focusing on an improvement of emissions per unit of economic development.[1,2] Intensity targets avoid the risk of limiting economic growth while allowing for participation

[1] Carbon intensity of the economy is defined as the carbon emissions per unit of GDP (C/GDP) not be confused with carbon intensity of energy use (C/E)(carbon factor).

[2] Intensity targets are one of the options for so-called dynamic targets, that is targets adjusted to certain development indicators. Dynamic targets are usually linked to economic development (GDP) but can be based on other indicators as well such as energy use (emissions per unit of energy use) or population (emissions per capita) (Philibert and Pershing, 2001).

in international emission trading.[3] In particular Philibert (2000) has argued that such targets could even be voluntary to avoid any possible negative economic consequences.[4] Although the intensity targets approach in principle only concerns the form of climate targets, and proposals have not been specific about how to differentiate intensity targets, it seems that the main principle behind the approach is that of capability: the contribution of countries to global greenhouse gas control should be related to their capabilities (opportunities and ability to pay). These could be related to per capita income, baseline projections as well as differences in mitigation opportunities, economic structure and energy resource base. While initially proposed as a first quantitative step for developing countries' participation, Philibert and Pershing (2001) have suggested it could also be the basis of commitments for all countries by differentiating the stringency of the targets. This option has now gained much policy relevance due to the Bush initiative.

3.3. Focus on need

A clear case of an approach that focuses on the need principle and the equal human right to development is the so-called "per capita emission rights" approach (see, for example, Agarwal and Narain, 1991). Instead of focusing on the question of how to share the emission reduction burden, it starts from the assumptions that the atmosphere is a global common to which all are equally entitled. It thus re-frames the issue as a resource-sharing problem. According to this approach, the global emission space should be shared on a per capita basis to secure an equal share for developing countries that accounts for their development needs. There have also been proposals made that in principle are based on equal per capita emission rights, but allow for a transition period from current emission levels. The first example of this was developed by the Global Commons Institute, known as "contraction and convergence" (Meyer, 2000). Taking into account the current situation, it proposes a convergence of per capita emission rights under a contracting global emission profile. Important policy variables in this approach are the level of contraction of global emissions, the convergence year, the rate of convergence and the extent that population growth is accounted for. Another proposal was made by Gupta and Bhandari (1999). They propose a transitional period for developed countries up to 2025 with burden sharing based on their relative emission intensities, before fully sharing emissions on a per capita basis amongst all countries.

3.4. Proposals combining principles

There have also been a number of proposals that combine (or could combine) various equity principles. Examples of such approaches are multi-criteria formulae, multi-stage or grouping approaches, Triptych and multi-sector convergence approach.

During the KP negotiations, there have been some proposals for differentiating emission reduction burdens on the basis of formulae including various criteria relating to responsibility (e.g. emissions, emissions per capita, emissions per unit of GDP and emissions per km^2), capability (GDP, GDP/capital and share of renewables in energy mix), need (population and share of energy/energy intensive products

[3] By targeting only an improvement in the level of emissions per unit of GDP, GHG intensity targets do not set an absolute emission limits. These may result in high costs if emission are much higher than expected. If the improvement in GHG intensity exceeds the target level this creates assigned amount units that can be traded (or banked for the future).

[4] In this proposal, countries are allowed to sell assigned amount units when they exceed their target level, but do not have to buy them if the underperform as the target is voluntary.

in exports), but also acquired rights (emissions) (Ringius et al., 1998; Depledge, 2000). They can be based on a small or large number of criteria, which can be given equal or different weights. Moreover, the approaches can be made dynamic by allowing for a change of the weights over time.[5]

Another approach that combines different equity principles is the multi-stage approach. The multi-stage approach consists of a system to divide countries into groups with different levels of commitments (stages). The aim of such a system is to ensure that countries with comparative circumstances in economic, developmental and environmental terms have comparative responsibilities/commitments under the climate regime. Moreover, the system defines when their level of commitment changes as their circumstances change. Generally speaking, the main equity consideration shifts from stage to stage, starting with a focus on need, shifting subsequently to capability and finally to responsibility. One proposal for such an approach is made by Gupta et al. (2001) using country criteria and so-called 'graduation profiles'.[6] Their graduation profile system is based on easily available comparable data, namely per capita income levels (capability principle) and CO_2 from industrial emissions (responsibility principle). Using a combination of these 2 criteria, 12 potential categories of countries are identified. Their system not only includes quantitative mitigation commitments, but also other types of commitments such as policies and measures and other qualitative obligations. A more simplified version of the multi-stage approach can be found in the FAIR model (den Elzen et al., 2001; Berk and den Elzen, 2001). In their approach, the number of parties involved and the level of involvement in global emission control gradually increases over time according to participation and burden sharing rules. These rules are not fixed, but can be selected from a range of options related to capability to act or responsibility. They consider four stages: (1) no quantitative commitments; (2) intensity targets; (3) emission stabilisation; and (4) sharing efforts of absolute reductions. An example of a multi-grouping approach is the Soft Landing approach developed by Blanchard et al. (2001) in which countries are subdivided into four groups (including Annex I) based on per capita income (ability to pay) and per capita emissions (responsibility). For the Annex I group further reductions after the KP are assumed, while for the other groups emission trajectories are differentiated based on different timeframes for emission stabilisation.

The Triptych approach is a sector-oriented approach that has been used for supporting decision-making in the EU prior to Kyoto (Phylipsen et al., 1998). It has subsequently been adapted for use at the global level (Groenenberg et al., 2001). It defines allowable national emission levels on the basis of specific rules for the following three sectors.

- *Domestic sectors* (residential, services, transport, light industry and agriculture). Emission allowances are based on convergence in per capita emissions.
- *Internationally-oriented energy-intensive industry*, where competitiveness is determined by the costs of energy and of energy efficiency measures. Here emission allowances are based on physical growth rates and energy and carbon intensity targets.
- *Electricity generation sector*, which shows greatest differences between countries (nuclear power, renewables, fossil fuel mix). Emission allowances are based on projections of electricity consumption, convergence in conversion efficiencies, de-carbonisation rates for the fuel mix and a targeted increase in the share of renewables.

[5] Note that "contraction and convergence" is an example of a dynamic two criteria approach with weights shifting from 1 to 0 for emissions and 0 to 1 for population during the convergence period.

[6] The term 'graduation profiles' is used in UN circles to define the movement of countries from one group to another for the purpose of specific obligations or benefits.

Recently, the Triptych approach has led to a similar, though more comprehensive approach, named the ‘multi-sector convergence approach’ (Sijm et al., 2001). It combines features of the per capita convergence and Triptych approaches. In principle, it aims at a converge of per capita emission levels, but tries to account for differences in national circumstances that cause variations of per capita emission requirements among countries. It groups emission sources into seven sectors for defining national emission allowances (electricity production, households, transportation, heavy industry, services, agriculture and waste), but this grouping could be adjusted. For each of these sectors global convergence rates are defined on the basis of global trends in activity level and emission factors. National emission allowances result from combining the sector allowances.

4. Compatibility of global climate change regime proposals with Article 2 of the UNFCCC

Many of the current proposals and debates on possible approaches to a global climate change regime have a short term focus because they concentrate on steps to make it attractive to some developing countries to join a global regime. They often fail to explore how such approaches would be able to meet the long-term requirements of Article 2 of the UNFCCC. How much room is there for greenhouse gas emissions if we want to stabilise concentrations at a level and within a time frame to avoid “dangerous interference with the climate system”? Because a decision on the appropriate stabilisation level is unlikely to be taken soon, uncertainty will be with us for some time. We, therefore, have to make decisions about near emission reductions in the light of possible long-term consequences (Berk et al., 2001; IPCC, 2001c). Current scientific knowledge suggests that the risks of climate change will be larger for higher stabilisation levels, but that even at relatively low CO_2 concentration stabilisation levels such as 450 ppmv risks are significant (IPCC, 2001a,c). For a 450 ppmv CO_2 stabilisation, global average temperature is projected to increase 1.5–4 °C in the longer term, depending on the value of the climate sensitivity (IPCC, 2001b) (see Fig. 2).[7] The risk of complete melting of the Greenland ice sheet over the next 1000 years or so, for instance, may become significant at the higher end of this temperature increase range, according to current models (IPCC, 2001b,c).

Given the way the global carbon cycle works, for any level of concentration stabilisation, global emissions have to peak and then decline to less than 50% of current values thereafter (IPCC, 2001c) (see Fig. 3). Meeting a 450 ppmv CO_2 stabilisation level around the year 2100 considerably narrows down the options for the short term: global emissions would have to peak in the next two decades or so and have to get below current levels before the middle of this century. Timing of mitigation then becomes critical.

One way to explore the various approaches outlined in the previous paragraph vis-a-vis the requirements of Article 2 is to quantify emission reduction regimes, which satisfy the 450 ppmv CO_2 stabilisation. One conclusion from such an evaluation immediately stands out: for stabilisation at 450 ppmv, reducing emissions of industrialised countries to zero and letting developing country emission trends untouched would not be enough. Developing countries would emit so much that the 450 ppmv level is quickly

[7] Note that these estimates include the contribution of other greenhouse gases. Stabilising CO_2 concentrations at 450 ppmv will thus result in a substantially higher CO_2 equivalent concentration (500–550 ppmv). In the calculations reported by IPCC, non-CO_2 emissions follow the SRES A1B scenario out to 2100 and are thereafter held constant. This assumption seems rather high. Based on our own assumptions, assuming also a reduction of non-CO_2 gases comparable to CO_2, CO_2 equivalent concentration would stabilise around 550 ppmv (Berk and den Elzen, 2001).

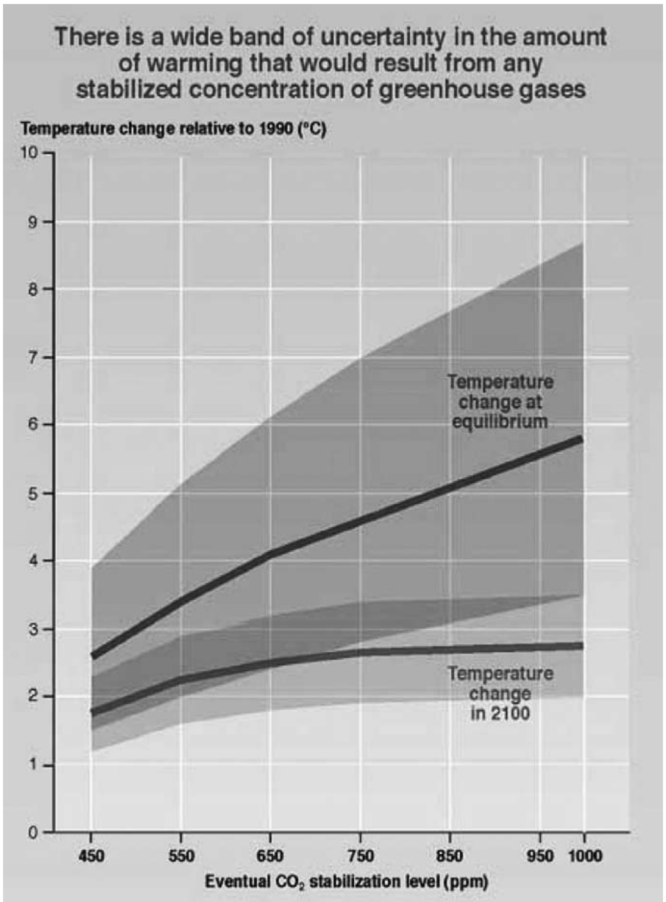

Fig. 2. Temperature changes relative to 1990 in year 2100 and at equilibrium are estimated using a simple climate model for the WRE profiles (Fig. 3). The lowest and highest estimates for each stabilisation level assume a climate sensitivity of 1.7 and 4.2 °C, respectively. The centreline is an average of the low and high estimates. Source: IPCC (2001c).

getting out of reach (Berk and den Elzen, 2001). In other words, increased participation from developing countries in the global effort to control climate change is needed. Let us look at such an exploration, done with the FAIR model, for two approaches, one based on intensity targets—associated with the capability principle—and one on convergence—associated with needs principle.

4.1. Intensity targets and multi-stage proposals

We first look at a subset of proposals, which suggest reductions of the carbon intensity (emissions per unit of GDP). With the FAIR model (den Elzen et al., 2001), we explored the implications of a de-carbonisation commitment approach for two cases: limiting global emissions to levels needed for stabilising long-term CO_2 concentrations at 450 and 550 ppmv, respectively. We assume that all *non Annex I countries* commit themselves after 2012 (start of the second commitment period) until at least 2050 to a de-carbonisation of their economies of 4% per year. The analysis is done against the background

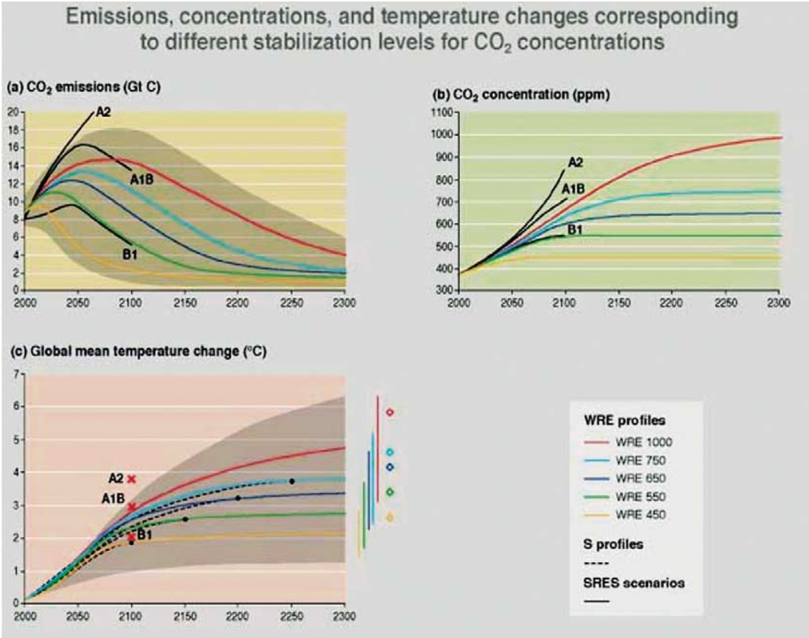

Fig. 3. Emissions, concentrations and temperature changes corresponding to different stabilisation levels for CO_2 concentrations and the SRES scenarios. Note: profiles and temperature changes have been calculated using a simple climate model for the WRE stabilisation profiles. The shaded area illustrates the range of uncertainty. Source: IPCC (2001c).

of the IPCC SRES A1B baseline scenario, a modest population and high economic growth, high-tech case (Nakicenovic et al., 2000). While historically de-carbonisation rates have been in the order of 1–2% per year, the A1B baseline assumptions of the de-carbonisation rates for the period till 2050 are in the order of (on average) 3% per year for developing regions (Nakicenovic et al., 2000) (see Fig. 6). Within the Annex I group the emission reduction effort—the level of emission reduction needed to remain below the global emission ceiling—is shared in proportion to their level of per capita CO_2 emissions after the first commitment period. Fig. 4 shows that the global ceiling for reaching 450 ppmv CO_2 is violated after 2030 because Annex I allowances have declined to zero and developing countries emissions are not sufficiently limited in time. In the case of a 550 ppmv CO_2 stabilisation level, the emission space left for Annex B would be strongly reduced (up to 70% by 2050 compared to 1990 levels). These cases are in fact already rather unrealistic by assuming high de-carbonisation rates for all developing countries. It seems more likely that such a system of de-carbonisation targets would start with middle income countries such as Korea and Mexico and would only be extended to other non-Annex I countries when achieving comparable income levels. The results of the analysis would then be even more negative: they would then also be incompatible with a 550 ppmv CO_2 stabilisation (see Berk and den Elzen, 2001).

We conclude that adopting only quantified commitments on carbon intensity reductions after the first commitment period for non-Annex I Parties will bring stabilisation levels of 450 or even 550 ppmv CO_2 probably out of reach. To stabilise CO_2 concentrations at levels around 450 ppmv, major developing countries like China and India will have to start participating in the global reduction efforts within a

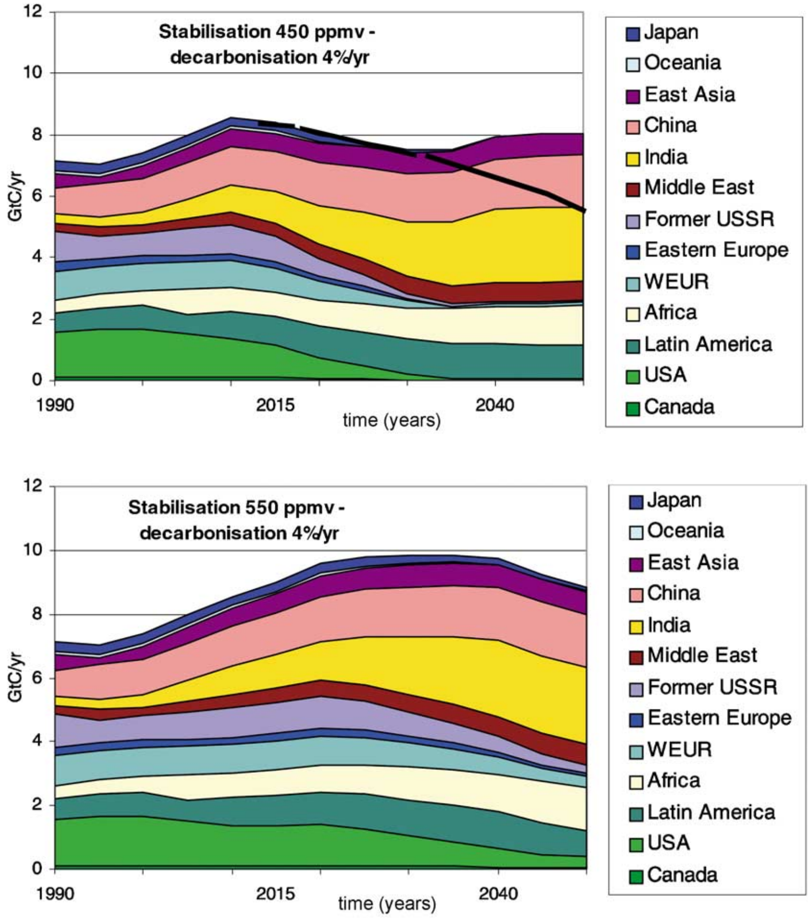

Fig. 4. Regional CO_2 emissions allowances for a regime aimed at stabilising CO_2 concentration at 450 ppmv (top) and 550 ppmv CO_2 (bottom) with a de-carbonisation target of 4% per year for all non-Annex I Parties after 2012 (start second commitment period). The solid line in the top figure indicates the emission profile for stabilising CO_2 concentration at 450 ppmv. Source: FAIR model. Note: the baseline is according to IMAGE SRES A1B. Burden sharing is based on per capita CO_2 emissions for the Annex I Parties after 2012.

number of decades—and at much lower levels of per capita income than the industrialised countries' average income in 1990 when they first agreed to undertake action.[8]

In theory a de-carbonisation rate commitment could be strengthened and/or additional commitments such as stabilising or reducing emissions could be introduced after reaching certain levels of income—the so-called multi-stage approach.[9] If we assume that after 2012 all non-Annex I countries adopt

[8] Another issue is how these intensity targets should be differentiated equitably—an issue not addressed yet. The approach is also hampered by major problems with comparability of GDP data: currency fluctuations make exchange rate based comparisons difficult to use. Even purchasing power parity comparisons are fraught with difficulties (Baumert et al., 1999; Müller et al., 2001).

[9] Note that if the de-carbonisation level equals the level of economic growth they de facto imply a stabilisation of emission levels, while higher de-carbonisation levels imply absolute emission reductions.

de-carbonisation targets of 4% per year and non-Annex I countries join the Annex B countries when their per capita CO_2 emissions reach the average world level, then staying within a 450 ppmv CO_2 stabilisation profile is theoretically possible (Berk and den Elzen, 2001). The political feasibility of such an approach in the case of low CO_2 stabilisation levels can, however, be questioned in view of the early acceptance and accession of greenhouse gas emission limitations by all developing countries. This would be the more difficult if no mechanisms are agreed upon to assist developing countries financially and technologically.

4.2. Convergence providing the right incentives?

We now turn to a second set of proposals that are in principle much better suited to ensure compatibility with Article 2, namely those that define allowable global emissions for attaining (or keeping open) long-term stabilisation levels and then distribute emission allowances among all countries. One of these is the convergence approach. We again used the FAIR model to analyse the distribution of emission allowances resulting from a linear convergence of per capita CO_2 allowances between 2012 and 2030 under global emission profiles for stabilising the CO_2 concentration at 450 and 550 ppmv, respectively. The baseline scenario is again the IPCC SRES A1B scenario. The result is strong reductions in allowable emissions for *Annex B* countries, in the order of 60–80% reduction below current levels by 2030 for a 450 ppmv stabilisation (Berk and den Elzen, 2001). Most developing countries are getting increasing emission allowances, but in the case of 450 ppmv stabilisation these increases are below baseline levels (see Fig. 5).

An advantage of this approach is that is does appeal to feelings of justice, particularly in developing countries. With an assumed universal participation of countries, such a convergence regime offers maximum opportunities for cost minimisation through a system of global emissions trading. Mitigation costs can be kept relatively low, even for industrialised countries that would face drastic reductions in emission allowances. Estimates are in the order of a few percentage points lower increase of global GDP at the end of a 50-year period—for projected GDP increases of 250% over this period (Berk et al., 2001; Hourcade et al., 2001). Developing countries could benefit from the associated emission trading because they generally have more low cost opportunities to reduce emissions. Disadvantages are also obvious: possibilities of large capital flows due to emissions trading, the uncertainty about the way this capital is going to be spent, the benefits of emissions trading would have to be realised in practice while no experience is available as of today with such a global system, and of course the drastic reductions in Annex B allowances are politically not easy to swallow.

5. Linking climate change to sustainable development: a promising approach?

Evidently, a politically acceptable way towards an equitable global climate change regime is difficult to find—are there alternatives? One possible alternative is to frame the debate not as an environmental problem, as industrialised countries have done, but as a development problem. It certainly would appeal to developing countries and would acknowledge that the quest for a more sustainable development pattern and the implementation of climate change mitigation and adaptation strategies can mutually reinforce each other (see Markanandya et al., 1998; Mills et al., 1991; Nakicenovic et al., 2000; IPCC, 2001a).

Would it be possible, starting from development objectives, to define actions to be taken by developing countries that at the same time promote sustainable development and greenhouse gas emission reduction? And could it, with targeted support from industrialised countries, help low-income

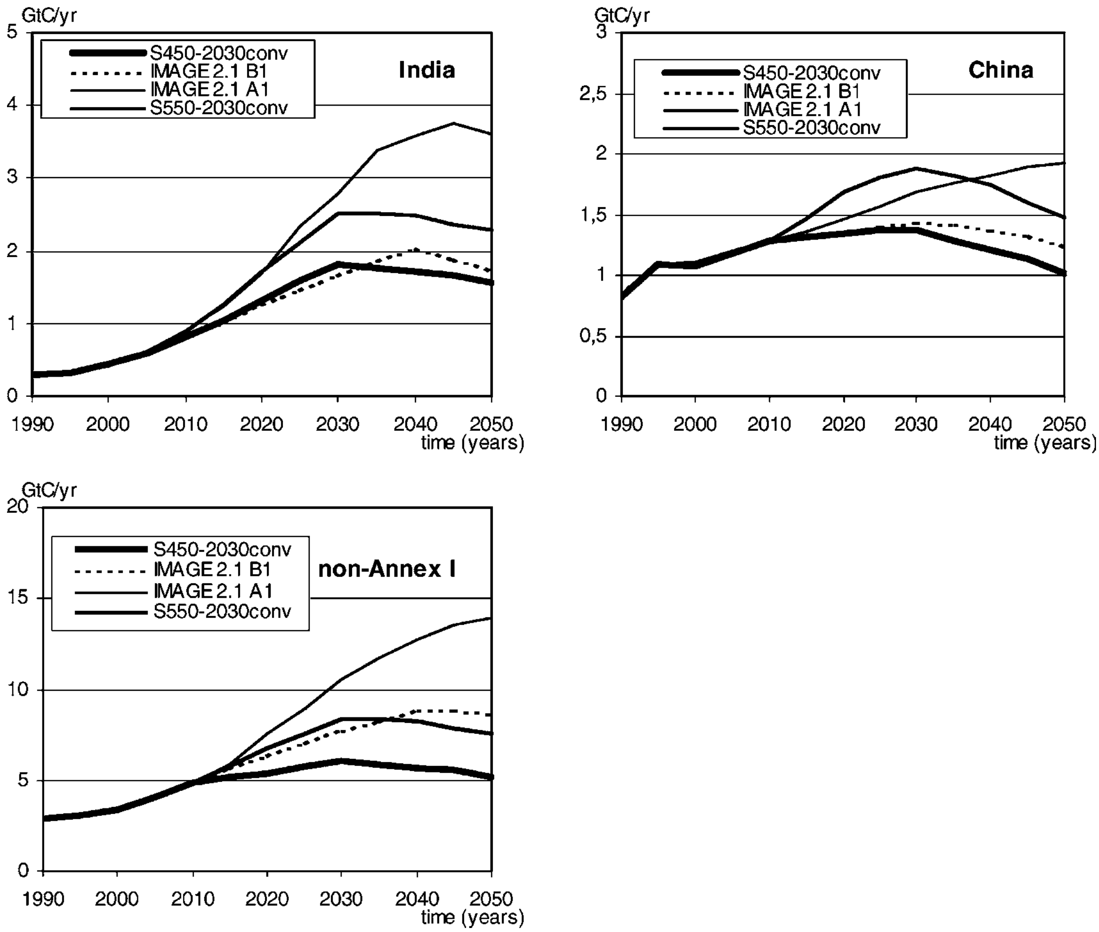

Fig. 5. CO_2 emissions for India, China and non-Annex I for a linear convergence of per capita CO_2 emissions between 2012 and 2030 compared to the IMAGE A1 and B1 baseline emissions for stabilising CO_2 concentrations at 450 and 550 ppmv. Source: FAIR model.

countries to acquire the knowledge, infrastructure and technologies required for such a transition? Could that be put together in the form of sustainable development agreements in the context of the UNFCCC?

We explore part of these questions by analysing the changes in energy efficiency and the de-carbonisation of the energy system that are required in the IPCC SRES B1 scenario (Nakicenovic et al., 2000; de Vries et al., 2000). This scenario describes a future world with a strong sustainable development orientation. Table 1 briefly characterises such a B1 world in terms of its lifestyle, socio-economic and governance dimensions. We take this scenario as one possible quantification of a future in which developing countries align their development goals towards equity, efficiency and sustainability.

The implications of this scenario have been explored with the IMAGE 2.2 model (IMAGE-team, 2001). One outcome is a comparison of the changes in energy intensity of the economy and carbon intensity of energy supply (carbon factor) in the B1 and B1-450 scenarios which meets a 450 ppmv CO_2 stabilisation

Table 1
The B1 story: main features

Demographic transition	
	Continuing rapid decline in fertility levels
	Increase in life expectancy
	Population 'greying' in IR, initially population 'greening' in LIR
Economic transition	
	Shift in IR to 'post-industrialist' values
	Highest growth in service sectors
	More openness and interregional cultural and economic exchange
	Present trends of globalisation and liberalisation continue
	Gradual decrease of interregional inequity in (monetary) income
	Competitive global industry in energy use/supply, car manufacturing, electronics and other high-tech areas
	R&D expenses as a fraction of GDP increase (nano-/biotechnologies)
Governance and institutions	
	Spiral of mutual trust between 'North' and 'South'
	International organisations gain authority and effectiveness
Environment and sustainability	
	Business commitment towards sustainable development
	Principles of sustainable resource use incorporated in production technology and consumer goods
	Environmental degradation in most regions stopped/reversed
Land and food	
	Trend away from the high-meat western-style diet
	Selective application of biotechnology
	Subsistence agriculture and fuel wood use decline
	Large food trade in a safe world
	Production of commercial biofuels becomes large business in some regions
Mobility, transport and communications	
	Urbanisation trends halted/reversed
	Investments in infrastructure, but emphasis on improvement of existing infrastructure, not expansion
	Rapid expansion of telecommunications and information technology
	Private car dominant transport mode

IR, industrialised regions; LIR, less industrialised regions.

level by the year 2100 (van Vuuren and de Vries, 2001). It is assumed that emission reduction measures take place where costs are lowest; no assumptions on the distribution of costs are made and we assume that the required technological and institutional adjustments happen without interference with the energy system.

Fig. 6 shows the annual improvement rates of energy intensity and the carbon factor for both the IPCC SRES A1B, B1 and the B1-450 scenarios. Results are given for three of the IPCC/SRES regions (Nakicenovic et al., 2000): OECD, Asia and the Africa–Latin America–Middle East (ALM) region. As it turns out, the service-oriented economic development and the less energy-intensive lifestyles assumed in a B1 world already increase the rate of energy intensity improvement by about 0.5–1.0% per year in all regions compared to the reference case (A1B), resulting into levels which do not exceed historical trends. In the B1 world, the rates for the OECD and Asia reach the upper end of historical trends in these regions

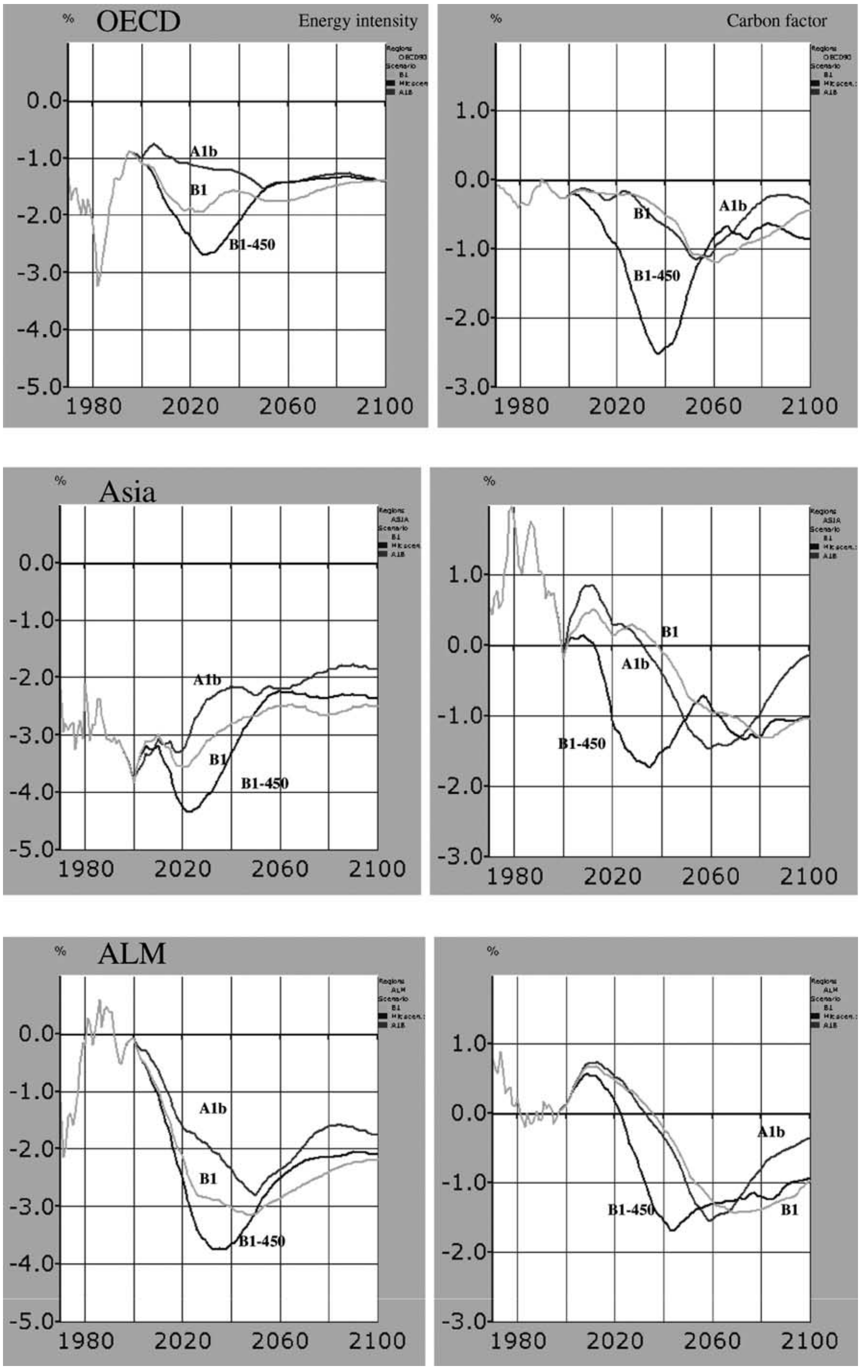

Fig. 6. Historic and future development of energy intensity (primary energy use per unit of GDP) and carbon factor (carbon emissions per unit of primary energy) in several macro-regions. Data are given for SRES scenarios A1B and B1 and for a B1-450 CO_2 stabilisation scenario, as implemented in the IMAGE 2.2. model (IMAGE-team, 2001).

between 1970 and 1995, while in ALM the rate of improvement is at a level that has historically occurred in the Asia region. In the past, the carbon factor trends have been either close to zero (OECD and ALM) or show an increase (Asia), for various reasons such as the fuel switches from traditional to commercial fuels. In the B1 scenario, the carbon factor will start to decline in the second half of the century at rates between 1 and 2% per year. This is induced by depletion of the easiest extractable fossil fuels which by then causes prices to rise and make alternative low-carbon options (conservation and renewables) more cost-competitive.

In our implementation, the B1 scenario leads to a more sustainable development than the A1B scenario in terms of environmental pressure and international income distribution, but it will not reach stabilisation at 450 ppmv CO_2. To achieve that, reductions in both energy intensity and carbon factor need to be accelerated. Fig. 6 shows that the carbon factor requires the largest increase. Energy intensity decrease will have to be 0.5% per year larger than in the B1 baseline. For the carbon factor, the rate of decrease goes to about 1–2% per year in all regions. Such rates, although historically unprecedented, could be reached without premature retirement of energy system investments. In the model calculations, normal lifetimes of power plants, industrial plants and other investments have been assumed, but for each new investment advanced technologies are chosen. The model also assumes a so-called technological learning effect that leads to cost reductions of advanced technologies with increasing deployment. The required increase of and shift in investments is relatively small (van Vuuren and de Vries, 2001; Morita et al., 2000, 2001).

In a sustainable development context climate change is just one of the problems to tackle. An effective strategy towards sustainability has to manage other environmental problems as well. For instance, the win–win opportunities in terms of reduced air pollution are very important in countries such as China and India, who currently suffer from high sulphur dioxide emissions resulting in significant health problems.

On the basis of this preliminary analysis of the energy sector there seem to be no major technical obstacles to the transition required for developing countries towards a sustainable development trajectory that meets a global 450 ppmv stabilisation. Some clear win–win dimensions seem to be present in this approach. Further analyses are however required, for instance, on the question how a sustainable development transition could be financed (Box 1).

5.1. Discussion

Rephrasing the need to reduce climate change risks from a greenhouse gas emission reduction into a development issue may in combination with the approaches discussed in previous paragraphs yield interesting new insights and options. For instance, when sustainable development (IPCC SRES B1 scenario) is assumed in the context of convergence, some developing regions, particularly India and Africa, would have emission allowances exceeding baseline levels. These allowances could be sold under an international emissions trading regime for which all countries in this system would automatically qualify. This would enable them to use that for modernising their economies and would pay for some of the costs of a transition towards sustainable development trajectories. Also in the case of a multi-stage approach the reconciliation with stabilisation of concentrations at low levels would be less problematic under assumptions of a sustainable development oriented world.

Generally, limiting climate change will become more easy if the world would develop into a more sustainable direction as depicted in the SRES B1 scenario. However, this does not mean that this type of world will come about easily. It will require social and institutional change supported by interventions

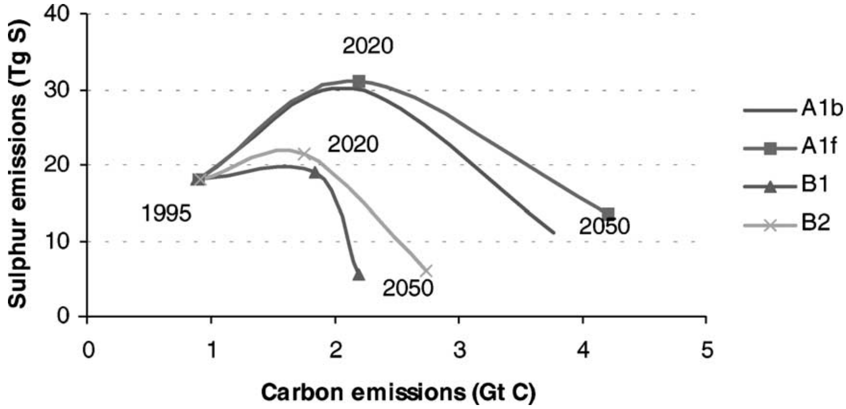

Fig. 7. Carbon and sulphur emissions for China in four of the SRES scenarios as implemented by IMAGE 2.2.

Box 1. China

Recently, the IMAGE-TIMER model has been used to assess some of the possible pathways for the energy system in China (van Vuuren et al., 2001). Two scenarios have been explored: the A1B-C scenario: an 'open' China in a globalised world, and the B2-C scenario: China geared to solving regional environmental problems. The main difference between the two scenarios is the energy demand, which, by the end of the century, is in the B2-C scenario only about half of that in the A1B-C scenario. The structure of energy use per sector follows a similar path in both scenarios, i.e. the share of industry decreases while the share of transport increases. Energy use in the residential sector increases only slowly, as people will use less low-efficient traditional biomass and more high-efficient and convenient energy. Two other scenarios are investigated: the B1-C scenario which is a future based on globalisation but time-oriented towards sustainable development, and the A1F-C scenario which shares many of its assumptions with the A1B-C scenario but assumes stronger technology development for fossil fuels and less development for new technologies.

In terms of air pollution, lower carbon emissions coincide with lower sulphur emissions. The sustainability oriented B1 scenario benefits in particular from this (see Fig. 7).

Eleven policy options and measures were analysed in detail with respect to the following.

1. *Strategic consequences*: Change in the dependency on imported fuels as a fraction of total primary energy use and/or as ratio of the energy import bill and GDP.
2. *Financial feasibility*: Increase in energy system investments as fraction of overall investments in the economy.
3. *Political feasibility*: Change in user costs as fraction of GDP or consumer expenditures.
4. *Effectiveness in terms of carbon mitigation*: Reduction of emissions compared to baseline.

The analysis does show that choosing a sustainable development pathway can indeed produce multiple benefits.

in a much broader area of policy making than environment/climate, like finance, trade, energy, transport, agriculture, etc. and thus also requires action in many other international institutions than the UNFCCC, such as the IMF, World Bank, WTO and specialised UN agencies.

6. Conclusions

We find that proposals for an equitable global regime to deal with climate change are often not evaluated with respect to their compatibility with Article 2 of the UNFCCC. This could be particularly problematic if a low-level stabilisation would be required to avoid dangerous interference with the climate system. Intensity targets, even when combined with multi-stage approaches, run the risk of not being able to keep the option of low-level stabilisation open. Convergence approaches have a better prospect, but would have to overcome other significant political problems. A sustainable development based approach might be able to overcome or at least reduce the political resistance against contributions from developing countries to reductions in greenhouse gas emissions, because this approach takes local development objectives into account. To increase its chance of success global climate change regimes should thus try to link up with broader sustainable development policies at both the national and international level as much as possible. One way of doing this could be to focus on architectures that define policy targets that also make sense from a sustainable development perspective, like improvement of energy efficiency, clean air policies or sustainable forest management, and allow for making technology and/or sector oriented agreements between industrialised and developing countries supported by means for technology transfer. These kind of agreements do not have to replace more general agreements on differentiation of climate commitments, but could become an integrated part. This could take the form of a climate regime that is sector and technology oriented in nature, like a global Triptych approach, or as supplemental arrangements to, for example, a per capita convergence regime to help directing capital flows towards sustainable development investments.

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