climate policy

research article

# Sector-based approach to the post-2012 climate change policy architecture

JAKE SCHMIDT, NED HELME, JIN LEE, MARK HOUDASHELT*

Center for Clean Air Policy, 750 First Street, NE, Suite 940, Washington, DC 20002, USA

A sectoral approach to GHG emissions reductions in developing countries is proposed as a key component of the post-2012 climate change mitigation framework. In this approach, the ten highest-emitting developing countries in the electricity and other major industrial sectors pledge to meet voluntary, 'no-lose' GHG emissions targets in these sectors. No penalties are incurred for failing to meet a target, but emissions reductions achieved beyond the target level earn emissions reduction credits (ERCs) that can be sold to industrialized nations. Participating developing countries establish initial 'no-lose' emissions targets, based upon their national circumstances, from sector-specific energy-intensity benchmarks that have been developed by independent experts. Industrialized nations then offer incentives for the developing countries to adopt more stringent emissions targets through a 'Technology Finance and Assistance Package', which helps to overcome financial and other barriers to technology transfer and deployment. These sector-specific energy-intensity benchmarks could also serve as a means for establishing national economy-wide targets in developed countries in the post-2012 regime. Preliminary modelling of a hybrid scenario, in which Annex I countries adopt economy-wide absolute GHG emissions targets and high-emitting developing countries adopt 'no-lose' sectoral targets, indicates that such an approach significantly improves the likelihood that atmospheric concentrations of $CO_2$ can be stabilized at 450 ppmv by the end of the century.

*Keywords*: climate change; developing countries; energy-intensity benchmark; financial incentives; no-lose target; post-2012; sector emissions; technology transfer

*Une approche sectorielle aux réductions des émissions de GES dans les pays en développement est proposée en tant qu'élément clé d'un cadre de mitigation du changement climatique à l'horizon post-2012. Selon cette approche, les pays en développement les plus émetteurs dans les secteurs de l'électricité et autres secteurs industriels importants, promettent de satisfaire des objectifs d'émissions des GES « sans perdants » dans ces secteurs. Aucune pénalité ne seraient encourue à cause d'un échec de conformité à ces contraintes, mais des crédits de réductions d'émissions pouvant être vendus aux nations industrialisées seraient accordés en cas de réductions des émissions au-delà du niveau de la contrainte. Les pays en développement participant établiraient des contraintes initiales « sans perdants », à partir de leurs circonstances nationales, sur la base de benchmarks d'efficacité énergétique spécifiques au secteur, développés par des experts indépendants. Les nations industrialisées inciteraient ensuite les pays en développement à adopter des objectifs d'émissions plus appuyés à travers un programme de technologie, financement et assistance « Technology Finance and Assistance Package », qui aiderait à surmonter les barrières financières ou autres au transfert et déploiement technologiques. Ces benchmark d'efficacité énergétique spécifiques aux secteurs pourraient aussi servir à établir des objectifs sur toute l'économie dans des pays en développement dans le cadre d'un régime post-2012. Une modélisation préliminaire d'un scénario hybride, dans lequel les pays de l'Annexe 1 adopteraient des objectifs absolus d'émissions de GES et les pays développés fortement émetteurs adopteraient des objectifs sectoriels « sans perdants », indique qu'une telle approche augmenterait considérablement la probabilité d'une stabilisation des concentrations atmosphériques de $CO_2$ à 450 ppmv d'ici la fin du siècle.*

*Mots clés*: benchmark d'intensité énergétique; changement climatique; post-2012; émissions sectorielles; incitations financières; objectif « sans perdants » ; pays en développement; transfert de technologies

*Corresponding author: *E-mail*: mhoudashelt@ccap.org

**CLIMATE POLICY 8 (2008) 494–515**
doi:10.3763/cpol.2007.0321  ISSN: 1469-3062 (print), 1752-7457 (online) www.climatepolicy.com

earthscan

## 1. Introduction

The primary objective of the United Nations Framework Convention on Climate Change (UNFCCC) is

> stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The Kyoto Protocol was designed to be a first step toward achieving the UNFCCC's overall aim, but it is much too limited in scale (the reductions in GHG emissions are modest when compared with the needed level), in scope (it establishes GHG emissions limits only in specific industrialized countries), and in time-frame to provide atmospheric stabilization of GHG concentrations. Negotiations on the structure of the next climate change policy framework are therefore exploring what approaches will be introduced in the post-2012 time-frame, which countries will participate, and what type of structure will apply to each participant.

Fully addressing post-2012 global climate change at the international level will involve:

1. Assessing the GHG emissions budget over a defined time-frame (e.g. 2012–2020)
2. Building emissions reductions contributions that maintain emissions below the emissions budget
3. Designing the 'architectural elements' for meeting the emissions reduction goals that are appropriate for particular groups of countries or companies.

The focus of this article is on the third step and its associated implications for Step 2.

A number of options have been proposed for the structure of the international response to addressing GHG emissions from industrialized and developing countries. To date, most of the proposals for developing countries have focused on mitigating GHG emissions from the economy as a whole. This article presents a different approach, instead focusing on the use of 'no-lose' (non-binding) emissions intensity targets to control emissions from particular economic sectors in developing countries, and suggests how such a 'sector-based' approach could be used to help establish national targets for industrialized countries as well.

Sector-based approaches have a number of possible advantages, including:

- *Ease of administration*: targeting emissions in a given sector is generally simpler than doing so economy-wide because, in many sectors, the number of actors is relatively small. This advantage may not apply in sectors that are characterized by a high degree of diversity or a large number of players.
- *Data availability*: in several sectors, emissions inventories or the underlying fuel data are already developed, even in developing countries, facilitating the rapid implementation of a reliable sectoral emissions reduction programme. Greater data availability also builds confidence, both domestically and internationally, in the emissions monitoring and reporting and thus smoothes international negotiations.
- *Greater equity*: some internationally competitive sectors in developing countries are equally or more GHG-efficient than those in Annex I countries, so a sector-based approach may be a 'fairer' way to reduce global GHG emissions than approaches that differentiate countries by income.
- *Increased technology transfer*: this approach creates a focused environment for global technology transfer and deployment.
- *Targeted emissions reductions*: the emissions sources or sectors with the highest priority for achieving emissions reductions, such as sectors that are energy-intensive or have slow turnover of invested capital, can be specifically targeted.

Sector-based approaches may also have some disadvantages, including:

- *Cost-effectiveness*: more cost-effective emissions reductions may exist outside of a covered sector, but this efficiency loss can be minimized by, for example, allowing emissions trading across sectors (while addressing leakage and free-rider concerns), setting emissions levels or benchmarks within other sectors as well, or using cost-effectiveness criteria to guide the level of emissions reductions established in the targeted sector(s).
- *Limited extent*: focusing on a few selected sectors will ignore emissions from sectors that may present a significant contribution to national emissions. Omitting specific energy-intensive or high-growth sectors may make achieving global GHG stabilization levels more difficult.
- *Leakage*: emissions can potentially 'leak' into uncovered sectors, depending on how the sectors are defined and the extent to which related products or activities are also simultaneously covered.

This article discusses a specific proposal for a sector-based approach to GHG emissions mitigation in the post-2012 framework which is based upon discussions among participants in the Center for Clean Air Policy's 'Dialogue on Future International Actions to Address Climate Change'. Other discussions of sectoral approaches and of non-binding emissions targets have been presented by Philibert and Pershing (2001), OECD/IEA (2002), Philibert et al. (2003) and OECD/IEA (2005), among others.

## 2. Overview of the proposal

In this sectoral approach, key developing countries would pledge to achieve voluntary 'no-lose' emissions intensity targets (e.g. tonne of GHG/tonne of steel) in major energy and heavy industry sectors (e.g. electricity, cement, steel, oil refining, pulp/paper and metals). In this context, the term 'no-lose' means that there is no penalty for not meeting the target, but there are positive incentives for exceeding it. Emissions reductions needed to meet a country's pledge are permanently 'retired for the atmosphere', while reductions achieved beyond the voluntary pledge are eligible for sale as emissions reductions credits (ERCs) to industrialized countries (see Figure 1). Failure to meet the voluntary pledge would not incur any penalties or require the purchase of ERCs from other countries.

The ideal sectoral programme would include all major developing countries, but particular emphasis on the inclusion of those countries that represent a major portion of each sector's operations and emissions will help minimize concerns about competitiveness and leakage. Participation of the ten highest-emitting developing countries in each sector generally ensures coverage of 80–90% of developing-country GHG emissions.

To encourage developing countries to pledge to meet more aggressive sectoral intensity targets, industrialized countries and international financial institutions provide assistance through a 'Technology Finance and Assistance Package'. This programme supports deployment of advanced technologies, development of small and medium-sized enterprises to assist in technology implementation, capacity-building activities, and pilot and demonstration projects. It would be designed to increase private sector investment by mitigating the risk of investing in advanced technologies and helping reduce the costs of these technologies in the future. This Technology Finance and Assistance Package would provide greater support to deployment of these advanced technologies than a simple awarding of carbon credits because, in many sectors, revenues from ERCs would be insufficient to provide the initial level of investment and technology transfer required to achieve significant early deployment of these technologies.

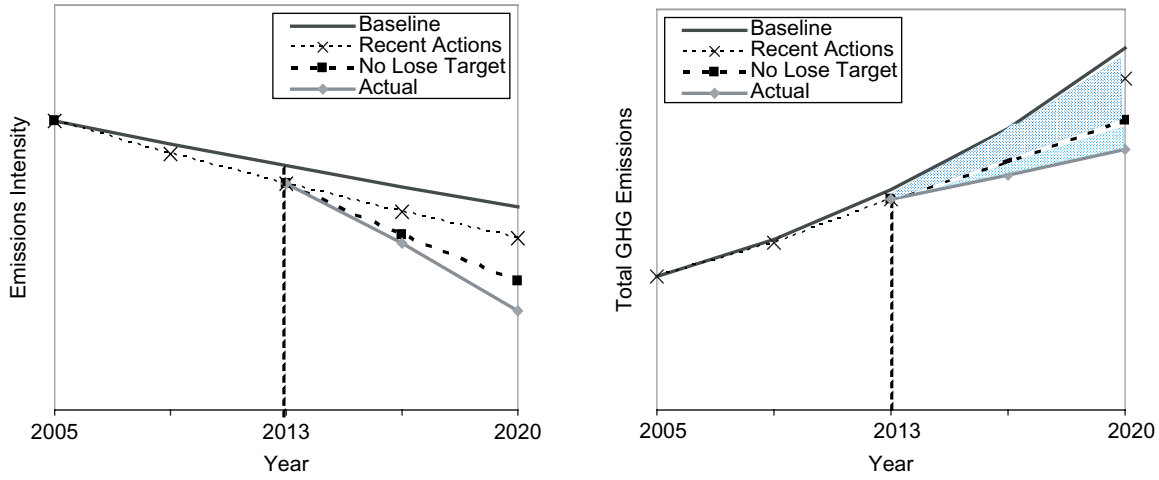


**FIGURE 1** GHG emissions 'permanently retired for the atmosphere' and emissions reductions available for sale when exceeding the 'no-lose' target. The left-hand and right-hand panels show the qualitative behaviour with time of sectoral emissions intensity and total sectoral GHG emissions, respectively. In both panels, the bold solid line represents the baseline (or business-as-usual) scenario, and the lighter solid line shows what actually occurs within the sector. The dotted lines with the X show the emissions intensity with recent actions. The dotted lines with the square show the emissions intensity target (left-hand panel) and the GHG emissions if this target is met (right-hand panel). The vertical dashed line designates the onset of the compliance period. The shaded areas in the right-hand panel represent the emissions that are 'permanently retired for the protection of the atmosphere' (darker shaded area) and the excess emissions available for sale (lighter shaded area).

The final sectoral GHG intensity pledges made by any participating developing country would result from negotiations between industrialized nations and that developing country. The initial building blocks for these negotiations would be benchmark energy intensity levels for major processes within each selected industrial sector; these benchmarks would be determined by internationally selected experts or institutes. Each developing country would assess the applicability of each benchmark to their domestic facilities and develop its own GHG emissions intensity pledges, taking into account factors such as the local fuel mix and costs. The level of assistance from the Technology Finance and Assistance Package would also factor into the negotiation process by lowering financial barriers to the achievement of lower energy intensity levels in the sectors. In the end, a developing country would adopt a single carbon intensity target or perhaps two targets, one for new facilities and the other for existing facilities, in each sector.

For industrialized countries, these energy-intensity benchmarks serve as the starting points for sectoral target negotiations. However, the final targets in industrialized nations are hard, aggregate, economy-wide emissions caps (i.e. similar to those under the Kyoto Protocol) that are built from the sectoral analyses. For developing countries, the final targets are GHG intensity targets that place no limits on the absolute growth in emissions in a given sector as long as GHG intensity improves.

Other sectors in developing countries (e.g. transportation, residential and commercial) remain eligible to participate in project-based, policy-based, programmatic or sectoral CDM (see Schmidt et al., 2006a, for a definition and distinction of these approaches), for which the full level of emissions reductions are eligible for sale.

## 3. Designing a sectoral programme

Several factors must be considered when establishing the structure of a sectoral approach to GHG emissions reductions. The most important of these are described below and some critical features of each are discussed.

### 3.1. Which sectors participate?

Global GHG emissions in 2000, ignoring land-use change and forestry (LUCF), were estimated at approximately 32,500 $MtCO_2e$ (Schmidt et al., 2006b; based upon data from: Olivier and Berdowski, 2001; Houghton, 2003; IEA, 2004a; Marland et al., 2004; USEPA, 2006). About 47% of these emissions originated in non-Annex I countries. Figure 2 shows how these developing-country GHG emissions were distributed among the major economic sectors in 2000 (Schmidt et al., 2006b; based upon data from: Olivier and Berdowski, 2001; Houghton, 2003; IEA, 2004a; Marland et al., 2004; USEPA, 2006) and how sectoral $CO_2$ emissions are expected to grow in this group of nations.

One of the key questions in a sector-based approach is which sectors to include because this influences the structure of such a programme. The electricity and major energy-intensive industry sectors – electricity, iron and steel, aluminium, oil refining, cement, lime, and pulp and paper – are well suited to the 'no-lose' sectoral GHG intensity targets defined in this article because they are each characterized by:

- a relatively small number of entities
- comparatively easy data collection

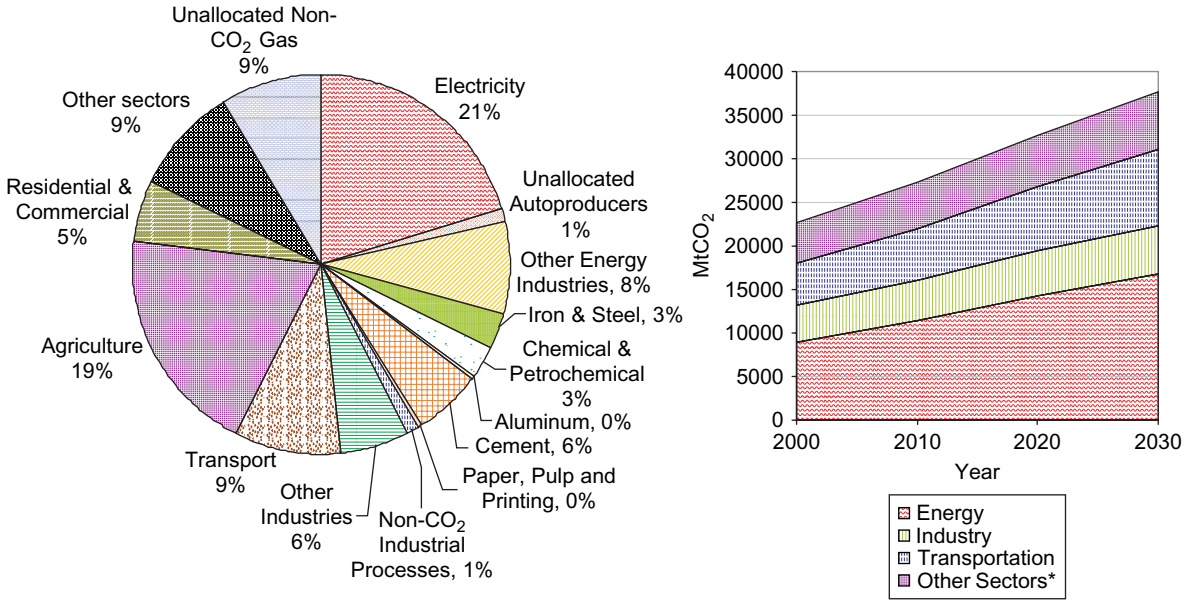


**FIGURE 2** Non-Annex I country GHG emissions (without LUCF). The left-hand panel shows the GHG emissions share by sector in 2000, and the right-hand panel shows major sector $CO_2$ emissions projections through 2030 (Year 2000 data from Schmidt et al., 2006b, based upon data from: Olivier and Berdowski, 2001; Houghton, 2003; IEA, 2004a; Marland et al., 2004; USEPA, 2006. Projections from IEA, 2004b).

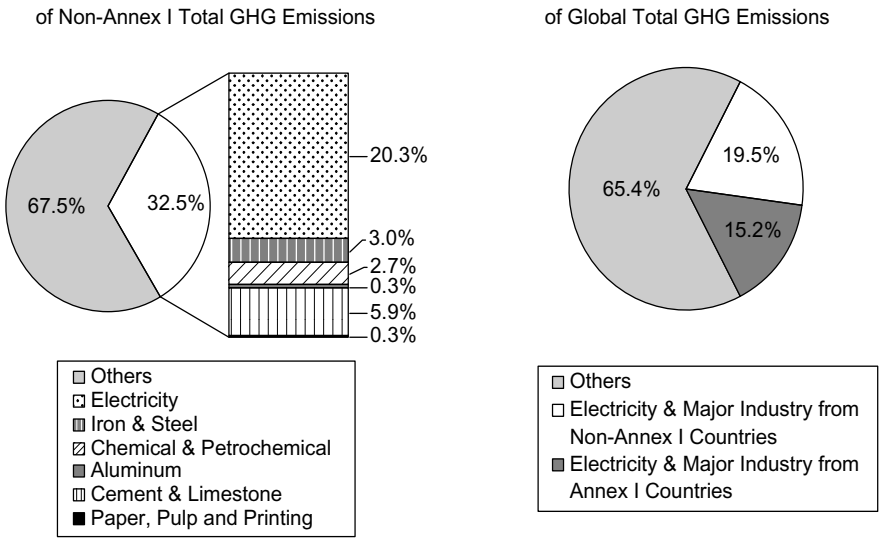


**FIGURE 3** Electricity and major industrial sector GHG emissions in 2000. Sectoral shares in non-Annex I countries are shown in the left-hand panel, and global shares appear in the right-hand panel (Schmidt et al., 2006b, based upon data from: Olivier and Berdowski, 2001; Houghton, 2003; IEA, 2004a; Marland et al., 2004; USEPA, 2006).

- fairly homogeneous products (except in the cases of oil refining and pulp and paper)
- participation in international trade (except in the case of electricity).

Most importantly, these sectors combined produce significant GHG emissions – approximately 33% of non-Annex I and 15% of global non-LUCF GHG emissions (see Figure 3). An additional factor driving this choice of sectors is the desire to include all sectors which directly compete with one another, in order to minimize the likelihood that the programme may provide indirect incentives for a non-covered competitive product. For example, if the iron and steel sector is subject to an emissions intensity target, while aluminium production is not, this could induce the substitution of aluminium for steel in applications for which either material is an option.

Since there is no universally accepted definition of a sector, and the existing GHG inventories do not, in all cases, break emissions into appropriate sector categories, we suggest using bottom-up criteria (e.g. combustion facilities above 20 MW) to define each sector. Furthermore, we propose that only the emissions associated directly with production in a particular facility be included in a sector's emissions, since it is clearly preferable to rely on a separate target for the electricity sector, as proposed here, to capture the emissions related to off-site electricity production.

### 3.2. An industry-based or country-based approach?

There are essentially two types of sector-based programmes – country-based programmes, in which individual countries are responsible for ensuring that the emission levels of the covered sectors meet the emissions intensity targets, and industry-based or transnational programmes, in which targets are established for an entire sector's operations worldwide (Watson et al., 2005). The latter approach seeks to address often-raised concerns about leakage (e.g. firms moving operations from covered to non-covered countries) and competitiveness (e.g. covering one firm but not its competitor).

We suggest that a sectoral approach be country-based for the following reasons:

- A small number of countries are generally responsible for the vast majority of the GHG emissions in each sector, as discussed below, thus addressing concerns about competition by the participation of a small number of countries.
- Countries have much clearer legal authority to ensure that firms operating within their borders comply with programme requirements. The establishment of a new legal institution to enforce sector-wide targets would be likely to require lengthy and contentious international negotiations. Even when international law has delimited clear precedents for regulating specific industries on a global basis (e.g. international aviation and maritime), the international agency developing the standards still relies upon countries to adopt and enforce them (Nieuwpoort and Meijnders, 1998; Cooper et al., 2003).

### 3.3. Which countries participate?

The sector-based programme proposed here aims to include all major developing countries, with emphasis placed on encouraging the participation of the countries responsible for the majority of the electricity and key industrial sectors' operations and emissions. Other countries would be free to join the programme, but the focus at first would be on those responsible for the majority of the emissions in the sector.

Fortunately, a relatively small number of nations account for a sizeable share of the developing country fraction of GHG emissions in most sectors – covering 80–90% of non-Annex I emissions for the electricity and major industrial sectors requires the participation of ten or fewer countries in each sector and only 20 developing countries overall (see Figure 4 and Table 1).

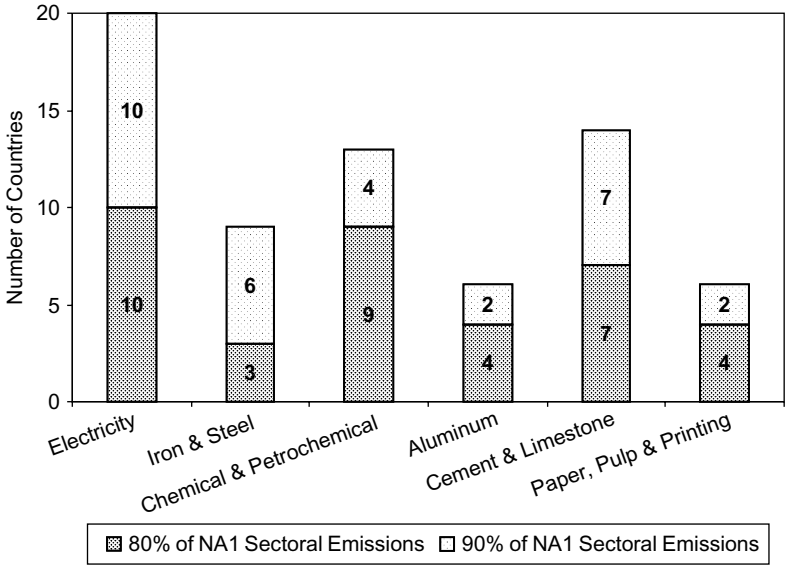


**FIGURE 4** Number of participating countries required to cover 80–90% of non-Annex I GHG emissions in particular sectors in 2000. The darker shaded regions of each bar show the number of countries responsible for 80% of developing country GHG emissions; the lighter shaded regions show the number of additional countries needed to achieve 90% coverage of developing country GHG emissions (Schmidt et al., 2006b).

**TABLE 1** Top ten developing-country GHG emitters for the electricity and major industrial sectors

| Electricity | Iron & Steel | Chemical & Petrochemical | Aluminium | Cement & Limestone | Paper, Pulp & Printing |
|---|---|---|---|---|---|
| China | China | China | China | China | China |
| India | India | India | Brazil | India | Brazil |
| South Africa | Brazil | U.A.E. | India | South Korea | South Korea |
| South Korea | South Africa | South Africa | Venezuela | Brazil | India |
| Mexico | Mexico | South Korea | Chile | Indonesia | Indonesia |
| Iran | South Korea | Brazil | Argentina | Mexico | Mexico |
| Saudi Arabia | Venezuela | Mexico | Bahrain | Thailand | Colombia |
| Kazakhstan | Indonesia | Iran | Kazakhstan | Pakistan | Thailand |
| Indonesia | Kazakhstan | Indonesia | South Korea | Egypt | Argentina |
| Thailand | Iran | Venezuela | Macedonia | Iran | Chile |

*Source*: Schmidt et al. (2006b).

In some sectors, a small number of non-Annex I countries also account for a relatively large share of the *global* GHG emissions, so participation by only a few developing countries can also affect a significant amount of certain sectors' worldwide emissions and cover a reasonable amount of overall global emissions. To illustrate this point, Figure 5 shows the percentage of global GHG

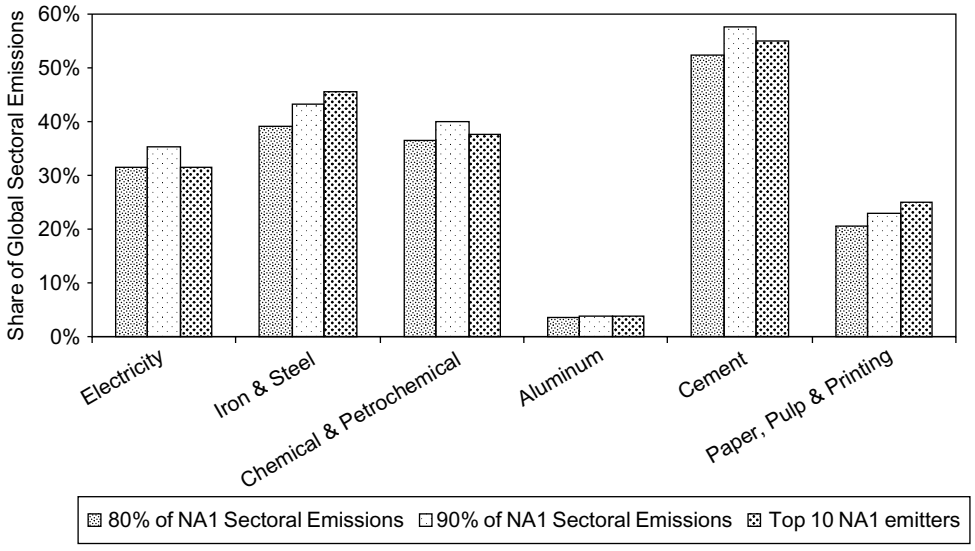


**FIGURE 5** Global shares of developing-country sectoral GHG emissions in 2000. The left-hand and middle bars for each sector show the percentage of global GHG emissions contributed by 80% and 90% of non-Annex I country emissions; the right-hand bar for each sector shows the percentage of global GHG emissions that originate in the ten highest-emitting non-Annex I countries (Schmidt et al., 2006b).

emissions covered by a programme that includes the ten highest-emitting non-Annex I countries for the sectors discussed here.

### 3.4. How is the 'no-lose' target established?

The final sectoral GHG intensity pledge made by each of the participating developing countries is produced through negotiation with the industrialized countries. Developing countries could have a single carbon intensity target for each sector or two targets; one for new facilities and the other for existing facilities in the sector.

A three-step process is envisioned for establishing an aggressive 'no-lose' target:

1. Experts assess and define energy-intensity benchmarks in each sector to use as a starting point for discussions.
2. Non-annex I countries pledge a carbon intensity level that they can meet without assistance.
3. Annex I countries negotiate with developing countries on specific financial and other support – through a Technology Finance and Assistance Package – to encourage non-Annex I countries to ultimately commit to stricter 'no-lose' emissions intensity levels.

Below, we discuss how each of these steps could proceed.

#### 3.4.1. Establishment of energy-intensity benchmarks

The initial building block for this negotiation will be an expert assessment of benchmark energy intensity (e.g. Joules/tonne of steel) levels for major processes within each selected industrial sector. This could be carried out by an international entity, by internationally selected expert institutes, or by some other designated benchmarking organization. Having an independent entity define the benchmark would ensure that the process of negotiation begins on a firm technical and economic basis, in much the same way that a 'Triptych' analysis served as the starting point for negotiations on burden-sharing within the European Union prior to Kyoto (Phylipsen et al., 1998; Groenenberg et al., 2001). We propose that the benchmarks be established through consideration of the following questions.

*Are the benchmarks tailored to energy mix?* We propose that the benchmarks be based upon energy intensity because this eliminates differences that are the result of variations in the fuel mix used in a sector or country. These energy-intensity benchmarks would later be refined to GHG emissions intensities through negotiations with each country, as described below.

*How many benchmarks are developed for each sector?* From a purely engineering standpoint, it is often desirable to have a large number of benchmarks to reflect the entire range of production processes in a sector. However, developing and using a large number of benchmarks in an international negotiation process is bound to be cumbersome and would present a barrier to effective negotiations. Therefore, the goal is to define a large enough number of benchmarks to reflect the major range of engineering differences between facilities, but not so many as to inhibit the international negotiation process. Therefore, we propose that the independent experts define a limited number of benchmarks (e.g. 1–3) to represent the major processes in each sector, taking into account considerations such as the availability of raw material substitutes.

*What technology type is chosen as a basis of the benchmarks?* We suggest that the benchmarks be based upon commercially available technologies, rather than technologies still under development. The independent entity could define separate benchmarks: one representing solely what is feasible from a technological and engineering standpoint and another that also accounts for the costs of the technologies (e.g. requiring a 2-year payback or less than $5 per unit of energy). For example,

the International Iron and Steel Institute (IISI, 1998) defined two separate benchmarks of these types: 'Eco-tech' and 'All-tech' benchmarks. Considering a range of economic threshold levels might also facilitate discussion of the 'no-lose' target and the Technology Finance and Assistance Package.

*How are existing and new facilities handled in the benchmark process?* We propose that separate benchmarks be developed for new and existing facilities in each sector to reflect the differences between the technical availability of emissions reduction technologies, the cost of retrofit technologies versus new facilities, and the degree to which existing facilities have been fully amortized. Alternatively, the differences between new and existing facilities could be handled by allowing more time for existing facilities to meet the benchmark.

*How would the benchmarks be updated?* Since technology is continually progressing, benchmarks would need to be updated regularly. The frequency of benchmark updating would be sector-dependent and subject to discussion, but it should be driven by the rate of technological progress in each sector.

### 3.4.2. Development of a country's domestic GHG intensity pledge

After the assessment of the energy-intensity benchmarks, each developing country would work to define a domestic *GHG intensity pledge* for each of the covered sectors. These countries would apply the energy-intensity benchmarks to their domestic facilities and then use the corresponding fuel mix to determine the analogous GHG intensity level for each participating sector. Each country would then pledge to unilaterally meet specific GHG intensity targets for both new and existing facilities, based upon the benchmark assessment, the likely impacts of the carbon intensity target on the competitiveness of its future exports from each sector, and other factors, such as its development objectives (e.g. improving air quality and providing for energy security).

### 3.4.3. Negotiation of the Technology Finance and Assistance Package

The international community would review the benchmark levels and each country's GHG intensity pledges to propose additional activities, facilitated through a Technology Finance and Assistance Package, for which it would provide support to assist these countries in assuming 'no-lose' GHG intensity targets that are more aggressive than their original pledges. This process would probably involve some give-and-take between each participating non-Annex I country and the international community to develop a robust country pledge and an appropriate and sufficient package of incentives. Further details of the Technology Finance and Assistance Package are discussed in Section 4.

### 3.4.4. Defining the final 'no-lose' target

Based upon a country's initial pledges and the support provided through the Technology Finance and Assistance Package, final 'no-lose' GHG intensity targets would be established for each developing country in the programme. In any sector, separate targets for existing and new facilities could be defined, or a single sector-wide target could be adopted. The latter type of target allows a country to receive credit towards their 'no-lose' target by instituting programmes that encourage a shift in the sector's operations from low- to high-efficiency facilities. Due to political and other differences between developing nations, we propose that each country be allowed to decide whether separate targets for new and existing facilities or a combined target for the entire sector is a better fit to their national circumstances.

Technological, economic and political differences between developing countries also make it unlikely that all countries will have the same 'no-lose' GHG intensity target for a given sector. However, since the ultimate targets are developed from the same starting point – the independently-defined energy-intensity benchmarks – a degree of comparability and equity is inherent in the target-setting process.

### 3.5. How are emissions reduction credits generated?

In the proposed approach, the final (negotiated) 'no-lose' target becomes the emissions crediting baseline. Emissions reductions beyond the final 'no-lose' target are assigned emissions reduction credits (ERCs) that are eligible for sale to Annex I countries. Calculation of the ERCs occurs in the following manner in each participating country:

- The total emissions and output (e.g. tonnes of cement) for each facility in the programme are calculated at the end of the target demonstration period.
- These totals are used to calculate the average carbon emissions intensity for all facilities in the programme.
- The total ERCs generated are then calculated by multiplying the difference between this average carbon intensity level and the country's carbon intensity target for the sector by the actual output in the sector.
- The country then decides whether and how to distribute the ERCs, or the proceeds of the sale of ERCs, to individual entities within the sector, without rewarding 'free riders'. An alternative would be to award ERCs directly to the covered companies, but this approach would be more complicated to design, requiring international negotiation to determine a policy for deciding which companies to reward, and would be less flexible.

The simplest way to accurately determine the number of ERCs generated from a given sector is to perform an *ex-post* calculation, when both the actual emissions rate and production levels are known (see Hargrave and Helme, 1998, for discussion of an *ex-ante* system). We propose that a sectoral approach be designed in a manner that generates credits *ex-post*, as described above, every 2 years during the compliance period. This enables entities (e.g. countries or companies) to participate in carbon-market trading during the same compliance period in which the emissions reductions occur. It also avoids enforcement problems that can occur in *ex-ante* systems when countries are overallocated ERCs.

## 4. Technology Finance and Assistance Package

In this sectoral approach, industrialized countries, international financial institutions (IFIs) and export credit agencies (ECAs) provide a package of technology finance and assistance incentives to help participating non-Annex I countries establish and meet more aggressive 'no-lose' targets through the development and more rapid introduction of advanced technologies. Industrialized countries would offer new commitments of funding that could be used to underwrite the cost of new, more expensive, climate-friendly technologies in key developing countries. Such a process could unfold through both bilateral and multilateral arrangements that are designed to make these new technologies available to firms in developing countries while providing reasonable profits and property rights protections for the industrialized-country entities that provide the technologies. In this sense, the entities in both developed countries – for example through return to their shareholders and access to new markets – and developing countries – for example through access to new, advanced technologies – will benefit.

### 4.1. The financial scope of the package

This new finance package would not be designed to fully support these advanced technologies but instead would be designed to leverage private sector investment by combining new financing

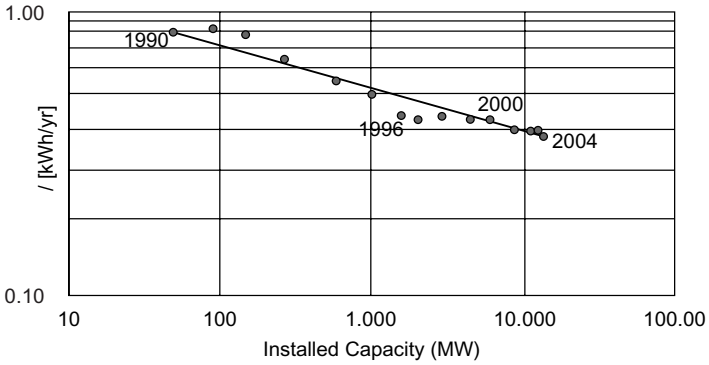


**FIGURE 6** Learning curve for wind energy in Germany. This curve shows how the cost of wind energy in Germany declined between 1990 and 2004, as the required technology improved and became more fully deployed (ISET, 2006).

from industrialized countries with existing developing country financing. The amount of money needed should be based upon a thorough bottom-up analysis of the financial and capacity barriers to meeting more aggressive GHG intensity levels than represented by the country's pledge. Different financing tools (e.g. risk coverage and 'soft' loans) would probably be used in each country, depending on the specific characteristics of their financial markets and the structure of each sector involved. In addition, the level of required international financing would be likely to decrease with time, and ultimately end, because economies of scale will lower the cost of a given technology as it becomes more widely deployed. A good example of this can be seen in Figure 6, which shows the diminishing cost of wind turbines in Germany between 1990 and 2003 that resulted from incentive programmes to catalyse the deployment of new technologies. The Technology Finance and Assistance Package would have a similar goal – namely to provide near-term incentives to demonstrate and deploy the technologies with the aim of bringing down the cost of these technologies over time.

### 4.2. What activities are supported?

Since the aim of the Technology Finance and Assistance Package is to help developing countries meet more aggressive 'no-lose' targets, the programme will strive to support activities that remove the major barriers to greater penetration and deployment of GHG-reducing technologies in the targeted sectors. In this regard, we propose that the support package could include the following specific activities:

#### 4.2.1. Demonstration and pilot project grants

For technologies that require further field-testing or have not yet been implemented in a specific developing country, financial and technical support would be provided for select demonstration projects and pilot tests. For example, developed countries could provide financial and technical support for demonstration IGCC-CCS plants in developing countries with significant coal resources (akin to the recent UK–China announcement on supporting such a facility; see *China Daily*, 20 November 2007). The goal would be to finance the incremental cost beyond that of conventional technology, while relying on conventional private and public investment to cover the base cost.

#### 4.2.2. Technology deployment and capacity-building activities

A direct grant, 'soft' loan, or other special lending provision (e.g. extended payback period, reduced fees, faster transaction processing, lower interest rate or premium, interest rate subsidy) could supplement existing financing to cover the additional cost of climate-friendly technologies in targeted sectors and make them competitive with other projects. In addition, investment in climate-friendly technologies to developing countries can actually produce more cost-effective emissions reductions than similar levels of investment in those same technologies in industrialized nations (Lefèvre, 2005).

## 5. How is the approach applied to Annex I Countries?

In a sectoral approach, Annex I countries would adopt national fixed emissions limits for the entire economy. We suggest that the sectoral benchmarks developed for use in establishing the developing country's 'no-lose' targets be used as building blocks for setting the national absolute targets for Annex I countries in a manner similar to the 'Triptych' approach, where the level of reductions that can be achieved in individual sectors are combined to produce an economy-wide target for a country (Groenenberg, 2002; den Elzen and Lucas, 2003; Höhne et al., 2005). The benchmarks would thus be applied to the electricity and major industry sectors in the developed countries to determine the assigned amount units (AAUs) for these sectors. Targets for the other sectors (e.g. transportation and residential) could be developed in a different manner and then combined with the AAUs for the electricity and major industry sectors to establish the economy-wide national AAUs. An iteration process may be required to reduce some individual sectoral AAUs to meet the desired overall target for the country (e.g. 30% below 1990 levels).

One of the major concerns in any international agreement is that a 'level playing field' should exist between the operations in a given industry from country to country. Even in a sectoral approach in which all developing country negotiations start from the same energy-intensity benchmarks in a given sector, the final 'no-lose' targets adopted by these countries will be likely to differ to some degree. While this could be interpreted as providing a competitive advantage to some countries, it is also consistent with the principle of common but differentiated responsibility and accounts for national circumstances, such as differing fuel mixes. A level playing field is facilitated by the proposed approach because the same benchmark level – reflecting comparable technology – will be used as the starting point for establishing the targets in industrialized and developing countries. Furthermore, for some industrial sectors, operations in many developing countries are more efficient than those in their industrialized counterparts (see Figure 7).

Level playing field concerns may also be raised because facilities in Annex I countries have the opportunity to trade to meet their targets – they can purchase allowances to cover any shortfall produced by incomplete implementation of a benchmark. At first glance, this might appear to violate the level playing field principle, but recall that facilities in developing countries face carbon intensity targets rather than absolute caps, allowing unlimited growth in production, while facilities in Annex I nations face hard emissions caps, so trading is needed there to permit growth in emissions caused by increased production. Overall, a sectoral approach may not produce a completely level playing field and address all aspects of competitiveness concerns in any given sector, but it moves the post-2012 process significantly in that direction by ensuring that a large share of global operations in a given industrial sector are now part of a similar regime, albeit an incentive-based rather than mandatory regime in the major developing countries. In particular, the distinction between an intensity-based regime in developing countries and absolute caps in industrialized countries introduces an intrinsic cost differential which may be problematic,

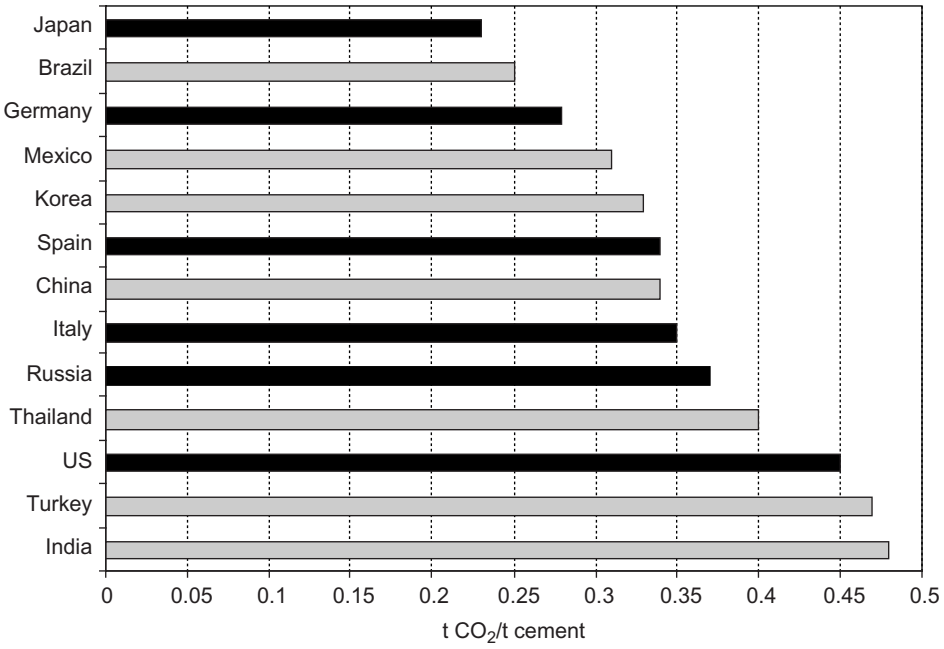


**FIGURE 7** $CO_2$ emissions intensity of cement production (excluding process emissions) in various countries. The dark and light bars represent emissions intensities in Annex I and non-Annex I countries, respectively. Note that there is no obvious distinction in emissions intensity between these two groups of countries (Hendriks et al., 1999; Price et al., 1999).

particularly in relation to internationally traded goods (which electricity, generally speaking, is not). The extent of this cost differential and impact on competitiveness depends on a variety of factors, some of which have been detailed in Grubb and Neuhoff (2006) and Demailly and Quirion (2006). Specifically, Grubb and Neuhoff (2006) detail the level of international competitiveness for some sectors in the European Union and emphasize that the distinction between how new and existing sources are handled is critical.

## 6. Emissions implications of a hypothetical sector target

To assess whether the proposed sectoral approach could achieve a level of global emission reductions by 2020 sufficient to preserve the opportunity for stabilization of atmospheric $CO_2$ concentrations at the 450–550 ppmv level in this century, three future GHG emissions scenarios were modelled. The 'mild' and 'strong' scenarios incorporated a combination of future emissions targets, made up of:

- absolute economy-wide targets in all Annex I countries except the USA
- a less ambitious national target in the USA
- no targets ('mild' scenario) or sectoral targets ('strong' scenario) in the cement, electricity, and iron and steel industries in the highest-emitting developing countries.

The third scenario consisted of only sectoral targets in all three groups of nations ('sectoral-only'). These scenarios are described more fully in Table 2. The outcomes of the models, discussed

**TABLE 2** Key assumptions in preliminary top-down analysis

| Scenario | Condition | |
|---|---|---|
| 'Mild' | Annex I excl. USA | 15% below 1990 level in 2020 |
| | USA | 10% above 1990 level in 2020 |
| | Non-Annex I | Reference |
| 'Strong' | Annex I excl. USA | 30% below 1990 level in 2020 |
| | USA | 1990 level in 2020 |
| | Non-Annex I | 'Sectoral' for electricity, iron & steel, and cement |
| 'Sectoral-Only' | All countries | 'Sectoral' for electricity, iron & steel, and cement |
| 'Sectoral' | Electricity | Reduction in carbon intensity of electricity production (tonne C/kWh) by 3% per year; growth in production reduced by 0.5% per year due to energy efficiency improvements |
| | Iron & Steel | Convergence in tonnes $CO_2$/tonne steel by 2025 to 0.80 (year 2000 average = 1.53) |
| | Cement | Convergence in tonnes $CO_2$/tonne cement by 2020 to 0.60 (year 2000 average = 0.77) |

below, are not intended to be definitive but are instead aimed at understanding the first-order implications of the sectoral approach proposed here.

### 6.1. Key assumptions and scenarios analysed

The modelling incorporated data on GHG emissions, energy use and physical production (e.g. tonnes of steel) for the electricity, iron and steel, and cement sectors in the following major Annex I and non-Annex I countries: EU-15, USA, Japan, Canada, Russia, Brazil, China, India, Mexico, South Africa and South Korea. These countries accounted for 72% of total global GHG emissions and 79% of the global emissions from the three listed sectors in 2000. In addition, these three sectors were responsible for 91% of the emissions produced by the electricity and major industrial sectors suggested for inclusion in the proposed sectoral approach.

For the selected countries, physical production, energy use and GHG emissions were collected from various international sources, mainly the International Energy Agency, the International Iron and Steel Institute, The US Geological Survey (IEA, 2003b; IEA, 2004a; IISI, 2004; USGS, 2004) and national sources. The resulting emission intensities per sector were calculated from the data.

For the scenarios involving sectoral GHG emissions targets, the sectoral emissions intensities were assumed to converge to similar levels by 2025 in the iron and steel sector and by 2020 in the cement sector, and to decline by similar rates in the electricity sector. While the scenarios define fixed limits for Annex I countries (e.g. 15% below 1990 levels), this does not necessarily imply that this level of reduction must occur domestically in those countries. Instead, Annex I countries could meet their national targets by purchasing emissions reductions from developing countries that perform better than their 'no-lose' targets or from other sectors in developing countries.

### 6.2. Preliminary results

Figure 8 shows how global GHG emissions evolve between 1990 and 2020 under the 'mild,' 'strong,' and 'sectoral-only' scenarios; the emissions reductions in 2020 produced in developing nations

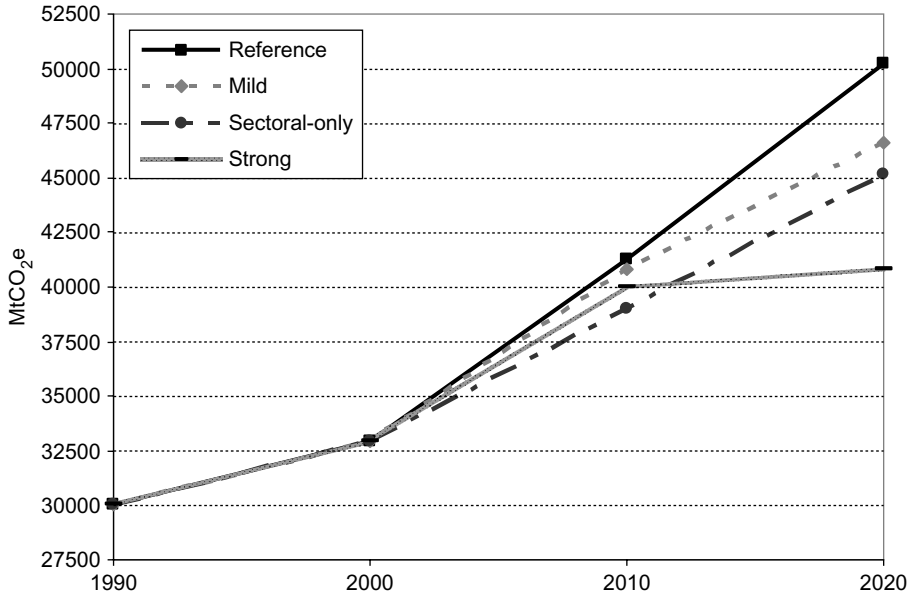


**FIGURE 8** Global GHG emissions under the sectoral scenarios. The bold line shows the behaviour of global GHG emissions between 1990 and 2020 under the reference scenario. The short-dashed, long-dashed and lighter solid lines show how global GHG emissions are reduced under the 'mild', 'strong' and 'sectoral-only' scenarios, respectively (Höhne et al., 2005). See Table 2 for descriptions of the various scenarios.

by the introduction of the proposed sectoral approach are illustrated in Figure 9. The 'sectoral' scenario described in Table 2 reduces GHG emissions (below the reference scenario) in developing countries in 2020 by 11% economy-wide and by 36% overall in the three participating sectors.

To assess whether these emission levels in 2020 are sufficient to stabilize $CO_2$ concentrations at a particular level, we assumed that, after 2020, total global emissions are reduced as quickly as possible. The inertia to change global emission trends was represented by the simple assumption that the global emission trend after 2020 cannot change by more than 0.5 percentage points per year. We used the MAGICC model (Wigley and Raper, 2001) to calculate the resulting $CO_2$ concentrations of the global emission pathways. For details of the methodology, see Höhne and Blok (2006).

All three of the modelled scenarios made sufficient reductions in global GHG emissions to permit stabilization of atmospheric concentrations of $CO_2$ at the 450–550 ppmv level by the end of the century, if emissions after 2020 are reduced further (see Figure 10). The 'strong' scenario understandably achieved the largest reductions, the 'sectoral' case was next best, and the 'mild' case reduced emissions the least. However, the 'mild' scenario requires three times the level of annual emissions reductions of the 'strong' case in the years between 2020 and 2050 (6.5% vs. 2.2% per year) to achieve atmospheric stabilization of $CO_2$ concentrations at 450 ppmv. The 'sectoral-only' case also requires significant annual reductions after 2020, on the order of 4% per year, to attain this stabilization level – this result underlines the importance of maintaining economy-wide caps for Annex I countries, rather than shifting to a global, intensity-based sector-only approach towards GHG emissions reductions.

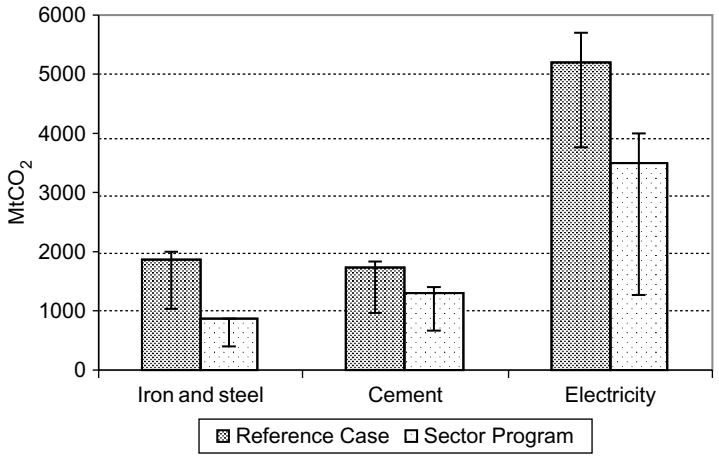


**FIGURE 9** Non-Annex I country model GHG emissions in 2020 in the electricity, cement, and iron and steel sectors. The left-hand bars for each sector show sectoral GHG emissions for the reference scenario, and the right-hand bars show emissions under the 'sectoral' scenario. The models indicate that GHG emissions in 2020 would be reduced by 54%, 25% and 33% from the reference cases in the iron and steel, cement and electricity sectors, respectively, by introduction of a sectoral GHG emissions reductions approach in developing countries.

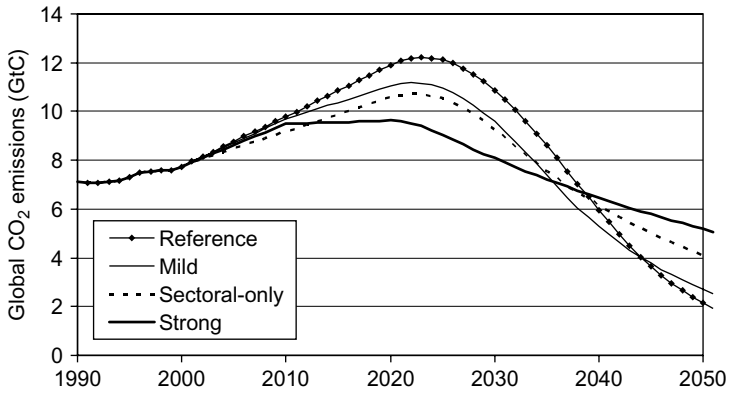


**FIGURE 10** Global $CO_2$ emissions required to stabilize atmospheric $CO_2$ concentrations at 450 ppmv in the sectoral models. From top to bottom in 2020, the lines represent the reference (points connected by solid line), 'mild' (light solid line), 'sectoral-only' (dotted line) and 'strong' (bold solid line) scenarios (see Table 2). For all scenarios, the model assumptions apply through 2020, and the emissions behaviour illustrated between 2020 and 2050 is a smooth representation of that required to achieve atmospheric stabilization of $CO_2$ concentrations at the 450 ppmv level by the end of the century.

## 7. Implications and next steps

One of the principal goals of the sectoral approach is to promote the use of best practices in internationally competitive industries around the globe. In practice, it aims to achieve the somewhat proverbial 'level playing field' and encourage technological innovation. This approach also offers a useful basis to resolve the continuing arguments in the EU ETS over the fairness of individual Member State allowance allocations. By developing consistent benchmarks in major industrial sectors, it could move this process towards a more consistent allocation of allowances.

### 7.1 Improving on the Kyoto Protocol

The sectoral approach marks an important departure from the current international structure because developing country carbon intensity targets constitute new contributions to the reduction of atmospheric concentrations of GHGs. Under the Kyoto Protocol, the developing country focus is on reductions achieved through the CDM; these replace rather than supplement emissions reductions that would otherwise be made by industrialized countries. A sectoral approach also allows explicit recognition and quantification of developing countries' unilateral efforts to reduce GHG emissions, independent of the CDM, such as China's fuel economy standards for new cars and Brazil's ethanol fuels programmes.

In the developing countries which participate in a sectoral programme, the pledge process supplants the CDM in the covered sectors. This approach improves upon the CDM because:

- It incorporates all facilities in a given sector in a participating developing country.
- Reductions achieved beyond a country's sectoral target are automatically 'additional' and available for sale; host countries no longer face uncertainties about additionality.
- Developing countries not participating in the sectoral programme, as well as entities in uncovered sectors of participating developing countries, can still carry out projects under the current or a revised (policy-based or sectoral) version of the CDM.
- The benchmarking process carried out in the proposed sectoral approach can assist the CDM Executive Board and its Methodology Panels to evaluate project-specific baselines and additionality for CDM projects in these sectors.

Most importantly, the proposed Technology Finance and Assistance Package encourages the development and transfer of new, climate-friendly technologies in developing countries and promotes precisely the technological innovation required for the world to achieve stabilization of global GHG concentrations at safe levels. It builds into the international process an explicit negotiation on technology finance between industrialized and key developing countries and mobilizes new public resources to leverage private investment and a portion of existing resources from the World Bank, other IFIs, and ECAs to promote technological innovation and GHG reductions.

### 7.2. Achieving the same goals through a modified CDM

The goals of the proposal outlined in this article could instead be achieved through the participation of these same sectors in 'sectoral CDM' (Figueres, 2006; Schmidt et al., 2006a), where certified emissions reductions (CERs) are only generated when a sector's emissions fall below a predetermined intensity level (e.g. a benchmark). The one major difference between sectoral CDM and the approach proposed here is that sectoral CDM would not necessarily provide a focused package of technology investments (Schmidt et al., 2006a).

### 7.3. Non-covered sectors

A key question for further consideration is whether a sector-based approach could be applied to the other sectors or sub-sectors (e.g. transportation, residential and commercial sectors). The specific structure proposed for the electricity and major industry sectors is probably not directly applicable to these other sectors, but similar programmes could perhaps be developed that reflect their unique characteristics; for example, a motor vehicle emissions intensity target of similar structure ($gCO_2$/km), based upon either rate of progress (e.g. 2% decline per year) or ultimate level (e.g. 100 g/km by 2020), could be introduced in the transportation sector (Houdashelt et al., 2006). Alternatively, non-covered sectors might be better suited to some form of the CDM – project-based, sectoral or programmatic.

Three sectors or sub-sectors seem potentially promising and warrant further consideration:

- *Land-use change and forestry* (19% of global and 34% of non-Annex I emissions in 2000); ten countries account for over 80% of global emissions (Schmidt et al., 2006b, based upon data from: Olivier and Berdowski, 2001; Houghton, 2003; IEA, 2004a; Marland et al., 2004; USEPA, 2006).
- *Transportation*, especially light-duty passenger vehicles (8% of global emissions in 2000, excluding LUCF, and growing rapidly in developing countries); 15 countries accounted for nearly 90% of passenger vehicle manufacturing in 2004 (International Association of Automobile Manufacturers, 2005), so such an approach could be applied in a limited number of countries and cover the majority of production.
- *Appliances* – residential appliances and equipment use 30% of the electricity generated in OECD countries (IEA, 2003a), and some appliances have substantial regional and global markets (Guéret, 2005), implying that collaborative development of appliance energy-efficiency standards in a limited number of locations could have much more widespread impacts.

### 7.4. Leakage

Philibert and Pershing (2001) discuss how sectoral targets are vulnerable to international and inter-sectoral leakage. However, the approach described here is designed to address each of these. International leakage is minimized by including all major GHG-emitting countries in each covered sector (e.g. the 'top ten'). Since the basis for the 'no-lose' targets – the energy-intensity benchmarks – are similar in each country, the incentive to shift operations to a country with lower standards is also reduced. Inter-sectoral leakage is reduced to some extent in this proposal through the judicious choice of participating sectors; most of the industries that experience serious competition from other sectors (e.g. steel and aluminium) would be covered. Of course, for any approach that does not cover the entirety of global emissions, as in this approach, leakage will continue to be a concern. Further consideration of the extent of leakage in a sectoral approach, versus that in other post-2012 proposals, warrants further consideration.

## 8. Conclusions

A sectoral approach to GHG emissions reductions should be a key component of the post-2012 climate change mitigation framework. Sectoral approaches for developing countries in the post-2012 regime have been attracting considerable attention, as evidenced at the May 2006 meeting of the Subsidiary Body for Scientific and Technical Advice of the UNFCCC, where a number of

interventions (by both industrialized and developing countries) mentioned the sectoral 'no-lose' approach as a potentially promising option for developing countries in the post-2012 climate change mitigation framework. In this approach, the ten highest-emitting developing countries in the electricity and other major industrial sectors pledge to meet voluntary, 'no-lose' GHG emissions targets in these sectors.

The final 'no-lose' emissions targets result from negotiations with industrialized countries. The starting points for these negotiations are energy-intensity benchmarks, developed by independent experts, for the electricity and major industrial sectors. From these benchmarks, the participating developing countries determine initial GHG emissions targets that are appropriate for their national circumstances. Industrialized nations then offer incentives for the developing countries to adopt more stringent emissions targets through a Technology Finance and Assistance Package, which helps them to overcome financial and other barriers to technology transfer and deployment.

Preliminary modelling of a hybrid scenario in which Annex I countries adopt economy-wide absolute GHG emissions targets, similar to those in the Kyoto Protocol but influenced by the aforementioned emissions-intensity benchmarks, and high-emitting developing countries adopt 'no-lose' sectoral targets, indicates that such an approach significantly improves the likelihood that atmospheric concentrations of $CO_2$ can be stabilized at 450 ppmv by 2050.

## Acknowledgements

This proposal has been developed from off-the record, informal discussions among senior climate change negotiators from over 30 industrialized and developing countries who are participating in the Center for Clean Air Policy's 'Dialogue on Future International Actions to Address Global Climate Change', which is funded by more than a dozen nations, as well as the Tinker Foundation. More information is available at: www.ccap.org/international/future.htm.

## References

China Daily, www. chinadaily.com.cn/china/2007-11/20/content_6267452.htm

Cooper, C., Park, D., Schmidt, J., Ulbrich, I., Winkelman, S., 2003, *Controlling Airport-Related Air Pollution*, Working Paper, Center for Clean Air Policy and the Northeast States for Coordinated Air Use Management, Washington, DC [available at www.ccap.org/docs/resources/147/2003-June—Controlling_Airport-Related_Air_Pollution.pdf].

Demailly, D., Quirion, P., 2006, '$CO_2$ abatement, competitiveness and leakage in the European cement industry under the EU ETS: grandfathering versus output-based allocation', *Climate Policy* 6(1), 93–113.

den Elzen, M.G.J., Lucas, P., 2003, *FAIR 2.0: A Decision-Support Model to Assess the Environmental and Economic Consequences of Future Climate Regimes*, RIVM Report 550015001, Bilthoven, The Netherlands [available at www.rivm.nl/bibliotheek/rapporten/550015001.pdf].

Figueres, C., 2006, 'Sectoral CDM: opening the CDM to the yet unrealized goal of sustainable development', *McGill International Journal of Sustainable Development Law and Policy* 2(1), 5–27.

Groenenberg, H., 2002, 'Development and convergence: a bottom-up analysis for the differentiation of future commitments under the Climate Convention', PhD dissertation, University of Utrecht, The Netherlands.

Groenenberg, H., Phylipsen, D., Blok, K., 2001, 'Differentiating commitments world wide: global differentiation of GHG emissions reductions based on the Triptych approach – a preliminary assessment', *Energy Policy* 29(12), 1007–1030.

Grubb, M., Neuhoff, K., 2006, 'Allocation and competitiveness in the EU emissions trading scheme: policy overview', *Climate Policy* 6(1), 7–30.

Guéret, T., 2005, *International Energy Technology Collaboration and Climate Change Mitigation – Case Study 3: Appliance Energy Efficiency*, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

Hargrave, T., Helme, N., 1998, *Growth Baselines: Reducing Emissions and Increasing Investment in Developing Countries*, Working Paper, Center for Clean Air Policy, Washington, DC [available at www.ccap.org/docs/resources/497/grow-int.pdf].

Hendriks, C.A., Worrell, E., de Jager, D., Blok, K., Riemer, P., 1999, *Emission Reduction of Greenhouse Gases from the Cement Industry*, International Energy Agency Greenhouse Gas R&D Programme, Cheltenham, UK.

Höhne, N., Blok, K., 2006, *The Impact of the Kyoto Protocol On Climate Stabilization: What is Next after the Kyoto Protocol? Assessment of Options for International Climate Policy Post 2012*, Techne Press, Amsterdam.

Höhne, N., Worrell, E., Graus, W., 2005, 'Emission reductions achieved from a sectoral approach', presentation prepared for the Center for Clean Air Policy's Dialogue on Future International Actions to Address Global Climate Change, Oslo, 19–21 April [available at www.ccap.org/docs/resources/498/Hoehne~Sector-Based%20Program%20GHG%20Implications.pdf].

Houdashelt, M., Winkelman, S., Helme, N., 2006, 'Reducing emissions from light duty vehicles: a sectoral approach', presentation prepared for the Center for Clean Air Policy's Dialogue on Future International Actions to Address Global Climate Change, Paris, 22 April [available at www.ccap.org/docs/resources/496/Houdashelt~Vehicle%20Techs%20Apr%2022.pdf].

Houghton, R.A., 2003, *Emissions (and Sinks) of Carbon from Land-Use Change*, Report to the World Resources Institute from the Woods Hole Research Center.

IEA (International Energy Agency), 2003a, *Cool Appliances: Policy Strategies for Energy Efficient Homes*, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

IEA (International Energy Agency), 2003b, *Energy Statistics and Balances*, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

IEA (International Energy Agency), 2004a, *$CO_2$ Emissions from Fuel Combustion: 1971–2002*, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

IEA (International Energy Agency), 2004b, *World Energy Outlook 2004*, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

IISI, 1998, *Energy Use in the Steel Industry*, International Iron and Steel Institute, Brussels.

IISI, 2004, *Steel Statistical Yearbook*, International Iron and Steel Institute, Brussels.

International Association of Automobile Manufacturers (OICA), 2005, *World Motor Vehicle Production by Country and Type: 2003–2004 OICA Correspondents' Survey*, 6 July [available at http://oica.net/wp-content/uploads/2007/06/worldproduction_cars2004.pdf].

ISET, 2006, *Efficiency of Wind Energy*, Excerpt of the Wind Energy Report Germany 2005, updated and revised reprint, Institute for Solar Energy Supply, Berlin [available at www.wind-energie.de/fileadmin/dokumente/Hintergrundpapiere/Wirtschaft_und_Strompreise/HG_Kosten_Effizienz_Windenergie.pdf].

Lefèvre, N., 2005, *Deploying Climate-friendly Technologies through Collaboration with Developing Countries*, IEA Information Paper, International Energy Agency, Paris, November.

Marland, G., Boden, T.A., Andres, R.J., 2004, 'Global, regional, and national fossil fuel $CO_2$ emissions', in: *Trends: A Compendium of Data on Global Change*, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, TN.

Nieuwpoort, G., Meijnders, E.L.M., 1998, 'The integration of economic and safety policy for shipping: the need for self-organization', in: H.E. Haralambides (ed.), *Quality Shipping, Market Mechanisms for Safer Shipping and Cleaner Oceans*, Erasmus Publishing, Rotterdam, 191–216.

OECD/IEA, 2002, *Beyond Kyoto: Energy Dynamics and Climate Stabilisation*, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

OECD/IEA, 2005, *Act Locally, Trade Globally: Emissions Trading for Climate Policy*, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

Olivier, J.G.J., Berdowski, J.J.M., 2001, 'Global emission sources and sinks', in: J. Berdowski, R. Guicherit, B.J. Heij (eds), *The Climate System*, Swets and Zeitlinger, Lisse, The Netherlands, 33–77.

Philibert, C., Pershing, J., 2001, 'Considering the options: climate targets for all countries', *Climate Policy* 1, 211–227.

Philibert, C., Pershing, J., Morlot, J.C., Willems, S., 2003, *Evolution of Mitigation Commitments: Some Key Issues*, Information Paper, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

Phylipsen, G.J.M., Bode, J.W., Blok, K., Merkus, H., Metz, B., 1998, 'Triptych sectoral approach to burden differentiation: GHG emissions in the European bubble', *Energy Policy* 26(12), 929–943.

Price, L., Worrell, E., Phylipsen, D., 1999, *Energy Use and Carbon Dioxide Emissions in Energy-Intensive Industries in Key Developing Countries*, Lawrence Berkeley National Laboratory, September.

Schmidt, J., Silsbe, E., Lee, J., Winkelman, S., Helme, N, Garibaldi, J., 2006a, *'Program of Activities' as CDM Projects: Implications of the Montreal Decision*, Clean Development Mechanism Dialogue Working Paper, Center for Clean Air

Policy, Washington, DC [available at www.ccap.org/docs/resources/72/CCAP_Program_of_Activities_CDM_Working_Paper_May_22_2006_x007E_FINAL.pdf].

Schmidt, J., Helme, N., Lee, J., Houdashelt, M., 2006b, *Sector-based Approach to the Post-2012 Climate Change Policy Architecture*, Future Actions Dialogue Working Paper, Center for Clean Air Policy, Washington, DC [available at www.ccap.org/docs/resources/68/Sector_Straw_Proposal-FINAL_for_FAD_Working_Paper.pdf].

USEPA (United States Environmental Protection Agency), 2006, *Global Anthropogenic Non-$CO_2$ Greenhouse Gas Emissions: 1990–2020*, Washington, DC [available at www.epa.gov/nonco2/econ-inv/pdfs/GreenhouseGasReport.pdf].

USGS, 2004, *Minerals Yearbook: Volume I, Metals and Minerals*, United States Geological Survey, Reston, VA.

Watson, C., Newman, J., Upton, S., Hackmann, P., 2005, *Can Transnational Sectoral Agreements Help Reduce Greenhouse Gas Emissions?* Background Paper for the OECD Roundtable on Sustainable Development, Organisation for Economic Co-operation and Development/International Energy Agency, Paris.

Wigley, T.M.L., Raper, S.C.B., 2001, 'Interpretation of high projections for global-mean warming', *Science* 293(5529), 451–454.