

Jotzo, Frank; Michaelowa, Axel

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## Estimating the CDM market under the Bonn Agreement

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DISCUSSION PAPER

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**Frank Jotzo**

**Axel Michaelowa**

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# **Estimating the CDM Market under the Bonn Agreement**

**Frank Jotzo**

**Axel Michaelowa**

This paper has been prepared within the Research Programme „International Climate Policy“ of HWWA.

## **HWWA DISCUSSION PAPER**

**Edited by the Department  
World Economy  
Head: Dr. Carsten Hefeker**

Hamburgisches Welt-Wirtschafts-Archiv (HWWA)  
Hamburg Institute of International Economics  
Öffentlichkeitsarbeit  
Neuer Jungfernstieg 21 - 20347 Hamburg  
Telefon: 040/428 34 355  
Telefax: 040/428 34 451  
e-mail: [hwwa@hwwa.de](mailto:hwwa@hwwa.de)  
Internet: <http://www.hwwa.de>

Frank Jotzo  
Pelangi [Policy Research for Sustainable Development]  
Jl. Danau Tondano, A-4, Jakarta 10210, Indonesia  
e-mail: [frank.jotzo@pelangi.or.id](mailto:frank.jotzo@pelangi.or.id)

Axel Michaelowa  
Hamburg Institute of International Economics  
Neuer Jungfernstieg 21, 20347 Hamburg, Germany  
Phone +49 40 42834 309, Fax +49 40 42834 451  
e-mail: [a-michaelowa@hwwa.de](mailto:a-michaelowa@hwwa.de)

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## **Abstract**

We analyse the impact of the agreement on implementation of the Kyoto Protocol achieved at COP6bis in Bonn in July 2001 on investment in greenhouse gas emission reduction projects in developing countries through the Clean Development Mechanism (CDM). The required actual emission reductions for participating Annex B countries overall will be relatively small, as the United States do not intend to ratify the Protocol and significant amounts of carbon sequestered in domestic sinks will be credited to Annex B countries under Article 3.4 of the Protocol. In addition, there is a large potential supply of surplus emissions quota (hot air) from Russia and other economies in transition. This means that demand for certified emission reductions (CERs) from CDM projects will be relatively small.

The magnitude of the CDM as a means for meeting Kyoto Protocol commitments, and individual countries' shares, will be influenced by a host of factors both on the demand and the supply side of the global carbon market. The analysis is based on a quantitative model of the global carbon market, based on marginal abatement cost curves and designed specifically for this type of analysis. We estimate required emission reductions in Annex B countries, the share of the Kyoto mechanisms in meeting this demand, the price for CERs, and the geographical distribution of CDM projects, and discuss distribution of sequestration projects. A 'low demand, low price' carbon market scenario appears likely, with intense competition between developing countries to attract CDM investors.

Sensitivity analysis illustrates the likely direction and magnitude of impacts when key supply and demand parameters are changed. We examine the impact of higher or lower implementation and transaction costs, as well as expanding or contracting the supply of CERs through baseline and additionality rules. While the CDM could suffer a loss in competitiveness if transaction costs are too high, changes in CDM supply parameters do not fundamentally change estimates of CDM size and revenue.

On the demand side by contrast there are a number of factors which could greatly reduce the size of the CDM, or even preclude commercially driven CDM projects altogether. Key factors that could harm the CDM are lower business-as-usual emissions growth in Annex B countries, higher supply of surplus emissions quota (hot air) from EIT countries, and possibly crediting under Article 3.4 of sequestration in

agricultural soils. If however the United States participated in implementing the Kyoto Protocol, none of these factors would be a threat to a viable and sizeable CDM.

We conclude that although the potential role for the CDM is seriously diminished under the Bonn agreement and without the United States on board, a significant amount of CDM projects in developing countries could still be achieved. Much will depend on international market factors, as well as the design of rules for CDM project implementation. The best strategy is to prepare to be competitive in a low-demand, low-price market, and at the same time to strive for the United States to still come on board the Kyoto Protocol.

### **Zusammenfassung**

Wir analysieren die Auswirkungen des Bonner Abkommens zur Umsetzung des Kyoto-Protokolls vom Juli 2001 auf Projekte zur Verringerung von Treibhausgasen in Entwicklungsländern (Clean Development Mechanism, CDM). Die von den Industrieländern insgesamt geforderte Emissionsverringerng ist bei Nichtteilnahme der USA relativ gering, da erhebliche Mengen in heimischen Senken gespeicherten Kohlenstoffs unter Art. 3.4 des Kyoto-Protokolls angerechnet werden. Außerdem gibt es ein großes Angebot überschüssiger Emissionsrechte aus Russland und anderen Transformationsländern (sogenannte „heiße Luft“). Daher wird die Nachfrage nach zertifizierten Emissionsreduktionen (CERs) aus CDM-Projekten relativ gering sein.

Das Gesamtvolumen des CDM und der Anteil einzelner Länder wird durch eine Vielzahl von Faktoren sowohl auf der Angebots- als auch der Nachfrageseite beeinflusst. Unsere Analyse basiert auf einem quantitativen Modell des globalen Treibhausgasmarktes. Wir ermitteln die in den Industrieländern erforderlichen Emissionsverringernngen, den Anteil der Kyoto-Mechanismen, den CER-Preis und die geographische Verteilung von CDM-Projekten generell sowie von Senkenprojekten im besonderen. Ein Szenario mit niedriger Nachfrage und niedrigen Preisen sowie intensivem Wettbewerb der Entwicklungsländer um CDM-Investoren erscheint wahrscheinlich.

Mittels Sensitivitätsanalysen analysieren wir die Auswirkungen von Veränderungen auf der Angebotsseite (Transaktionskosten und unterschiedliche Regeln für die Bestimmung von Referenzfällen und Zusätzlichkeit). Während hohe Transaktionskosten die



Wettbewerbsfähigkeit des CDM stark einschränken können, sind die anderen Faktoren von untergeordneter Bedeutung. Dagegen können diverse Faktoren auf der Nachfrageseite den CDM stark reduzieren oder völlig überflüssig machen. Dabei handelt es sich um niedrigeres Emissionswachstum im business-as-usual-Fall, höheres Angebot an „heißer Luft“ und Speicherung in landwirtschaftlichen Böden. Falls jedoch die USA teilnehmen, würde keiner dieser Faktoren den CDM ernsthaft bedrohen.

Wir kommen zum Ergebnis, dass trotz der starken Einschränkung des CDM durch das Bonner Abkommen und das Fernbleiben der USA eine relevante Menge an CDM-Projekten in Entwicklungsländern zustandekommt. Viel hängt von den Regeln für die Umsetzung des CDM ab. Die beste Strategie ist die Vorbereitung auf einen Markt mit niedriger Nachfrage und niedrigen Preisen. Gleichzeitig muss versucht werden, die USA zur Teilnahme am Kyoto-Protokoll zu bewegen.

# 1 Introduction

After more than three years of negotiations and despite of the hostility of the Bush Administration towards the Kyoto Protocol, the 6<sup>th</sup> Conference of the Parties to the U.N. Framework Convention on Climate Change in July 2001 achieved an agreement on issues that had remained open or unclear under the Protocol. The Bonn Agreement paves the way for ratification and entry into force of the Protocol without the U.S.. However, this necessitated concessions to many participating countries resulting in an loosening of emission reduction commitments. The main decisions in this respect are:

- The acceptance of forest management as carbon sinks with country-specific ceilings (including JI) summing up to 302 million t CO<sub>2</sub> per year for the whole of Annex B.
- The acceptance of other sinks categories (agricultural soils, revegetation) without any ceiling, adding a potentially huge amount (see Appendix) in the order of magnitude of forest management.
- Accepting afforestation and reforestation under the Clean Development Mechanism (CDM) but limiting it to 1% of Annex B base year emissions, i.e. 183 million t CO<sub>2</sub>.

Another main feature of the Bonn Agreement is that there are no limits on use of the mechanisms and that emission rights are fungible. Nuclear power projects are de facto excluded from the CDM and Joint Implementation (JI). CDM-relevant decisions are as follows:

- The small scale projects that shall get preferential treatment have been defined (less than 15 MW for renewable projects, less than 15 GWh annual savings for efficiency projects and less than 15kt annual CO<sub>2</sub> emission for all others).
- The adaptation tax is set at 2% of certified emissions reductions (CERs) and not extended to the other mechanisms.
- The rules for determination of additionality and baselines are still unclear.

We look at the impacts of the Bonn Agreement on supply and demand of emission credits on the international market to derive conclusions about the likely impact on the CDM.

## **2 Modelling framework**

The modelling tool used in this analysis is a model of the global carbon market under the Kyoto Protocol, PET (Pelangi's Emissions Trading) model. The model is based on marginal abatement cost curves. Here we give an overview of the modelling approach, key parameters, and assumptions in the standard scenarios – see appendix 1 for more detail.<sup>1</sup>

### **2.1 The model**

Analysis in this paper is based on a quantitative model of the implementation of the Kyoto Protocol, with a particular focus on the CDM, named PET (Pelangi's Emissions Trading model). It uses information on baseline emissions and emission reduction activities in Annex B countries, emission offsets achieved in developing countries through the CDM, and institutional features of the global market for carbon credits. PET allows for comparative analysis of the impacts of different market scenarios and implementation rules on the CDM. Its main application so far has been in the World Bank's *National Strategy Study* on CDM in Indonesia (State Ministry of Environment of the Republic of Indonesia, GTZ, World Bank 2001).

The PET model is essentially a supply/demand model for a single commodity: carbon emission credits. It is assumed that these credits will be traded in a perfect international market, so that there is a single global price for emission credits, including for those from CDM projects (Certified Emissions Reductions, CERs). The model finds the equilibrium distribution of abatement between countries, and the international trade flows – in other words, who produces, buys and sells how much of the commodity 'carbon reduction'.

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<sup>1</sup> PET has been developed at Pelangi Indonesia [Policy Research for Sustainable Development]. It is a relatively simple, easy-to-use package geared towards policy scenario analysis. A downloadable version and associated documentation are available at [www.pelangi.or.id](http://www.pelangi.or.id).

Supply and demand curves are derived from marginal abatement cost (MAC) curves, which plot the incremental cost of reducing emissions in different countries and regions. The MAC curves differ between countries, depending on the magnitude of emissions and the availability and cost of options to reduce them. The curves for the general energy sector are derived using the output of computable general equilibrium (CGE) models, which can capture a country's economic structures in great detail (see Grütter 2000, Ellerman and Decaux 1998, Polidano et al. 2000). Additional information is incorporated for emissions and abatement from gas flaring and no-regrets options, as well as for sequestration in sinks. For developing countries, the aggregate MACs from the four abatement categories are equivalent to the (pre-adaptation tax) CDM supply curve.

The model provides a financial-technical analysis of emission reductions and carbon trade. The model provides a 'snapshot' representation of the global carbon market in the year 2010 as an approximation of averages over the first commitment period under the Kyoto Protocol (2008 - 2012). CER accumulation in the years 2002-08 is included.

## **2.2 Calibration**

The MAC curves for the general energy sector in PET are calibrated based on those derived from the MIT's EPPA model (Ellerman and Decaux 1998), for those countries where such data are available. The MAC parameters for the EPPA model are taken from the World Bank's CERT model (Grütter 2000), with additional information from Ellerman and Wing (2000). The parameters for abatement in the general energy sector are for reductions in emissions of carbon dioxide from combustion only. As the regional disaggregation in PET is more detailed than the published data from the CGE models used for calibration, further estimation and calibration of MAC curves in specific developing countries was undertaken – see appendix for details.<sup>2</sup>

Emissions data for carbon dioxide, in particular business-as-usual projections to 2010, are taken from US Department of Energy (2000) forecasts. These data are crucial

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<sup>2</sup> It has to be noted that the underlying parameters were derived in simulations where all Annex B countries meet their Kyoto commitments, including the United States. In the analysis here by contrast, the United States are assumed not to participate. This has implications for the industrial competitiveness of countries, and would change the MAC parameters somewhat. However, we would expect the effect to be relatively small and would not expect the direction and magnitude of key results to change significantly if adjusted MAC parameters were used.

insofar as they determine the magnitude of emission reduction required to meet Annex B Kyoto commitments, relative to business-as-usual.

The second category of emission reduction options under the CDM modelled is reduction of gas flaring which can become important for oil- and gas producing countries. Using flared gas for energy production, thus displacing other emissions, is likely to provide relatively high volumes of emission offsets at low cost under the CDM. Exponential cost functions with steeply increasing slopes are used, reflecting the assumption that abatement costs are low for many installations but increase steeply as these low cost options are exhausted.

Sequestration activities (sinks) are included as fixed-cost and fixed-quantity abatement options. This reflects the provisions for the implementation of the Kyoto Protocol limiting the use of sinks towards achieving targets. No-regrets abatement options under the CDM can also be included in PET modelling.

Transaction costs are modelled as upward shifts in the MACs of developing countries, implying that project participants bear the full transaction costs. The PET model also includes a CDM tax (adaptation fund levy) on the sale of CERs. Again, the underlying assumption is that these costs are borne by the supplier of CERs; the tax thus drives a wedge between the marginal cost of abatement in developing countries and the supply price in the market.

### **2.3 Assumptions in the standard scenario**

The main parameters used in the standard modelling scenario are as follows and will be explained in detail in chapter 3:

#### **Emission reduction requirements and abatement in OECD Annex B countries, and supply of emission offset credits from EIT countries**

- All Annex B countries except the United States comply with their Kyoto commitments.
- Emissions reduction requirements relative to business-as-usual based on USDoE (2000) forecasts, and taking into account credits for sinks under Article 3.4 of the Protocol, both for forest management and agricultural soils (see table 1).

- Cost of domestic abatement in Annex B regions: Country specific marginal abatement cost curves for abatement of carbon dioxide emissions, based on MIT-EPPA. For countries with surplus emission quota (such as Russia), the marginal abatement cost curve is equivalent to the JI supply curve, when accounting for transaction costs.
- Sales of 'hot air' (surplus AAUs from EIT countries) assumed to be limited to 400 Mt CO<sub>2</sub>/year.

### **Emission reductions in non-Annex B countries under the CDM**

- Participation of all developing countries in the CDM; differentiation in supply according to technical potential and costs.
- Emission reductions in the energy sector: Country specific marginal abatement cost curves, based on MIT-EPPA where available.<sup>3</sup> Range between 3.5 (Brazil) and 12 percent (China) of business-as-usual emissions at 2010 at a credit price of \$2/tCO<sub>2</sub>.
- Reduction in emissions from gas flaring: around 40 percent of most recent emission levels at a credit price of \$1.50/tCO<sub>2</sub>.
- No no-regrets projects: All energy projects have positive technical implementation costs. This assumption of course crucially depends on the final, detailed rules for an additionality check under the CDM.
- Sinks CDM projects: 1 per cent of assigned amounts of OECD Annex B countries. Combined implementation and transaction costs \$0.50/tCO<sub>2</sub>. Distributed among non-Annex B countries according to shares in estimated sinks potential.

### **Transaction costs**

Transaction costs are differentiated between mechanisms to reflect differences in the costs for certification, for example reporting and verification requirements. Assumptions used in the standard scenario are

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<sup>3</sup> MIT-EPPA parameters are available for most key non-Annex B regions in PET; for the remaining regional groupings, either proxy parameters for comparable country groups are used, or parameters estimated based on a comparison of the structure of the energy system in these regions. For Indonesia, the marginal abatement cost curve is constructed using bottom-up analysis of abatement options and costs (see State Ministry of Environment of the Republic of Indonesia, GTZ, World Bank 2001).

- \$0.75/tCO<sub>2</sub> for CDM projects
- \$0.50/tCO<sub>2</sub> for JI projects (i.e., sales of emission credits from emission reduction projects in EIT countries)
- A nominal amount of \$0.10/tCO<sub>2</sub> for sales of assigned amounts units (AAUs/‘hot air’).

### **Taxation and revenue allocation**

- Adaptation levy (CDM tax): 2 percent of the proceeds from certified project activities, paid by the project participant.
- The host country is assumed to bear the full cost of project implementation and to receive the full revenue from the sale of the resulting CERs at the market price.

## **3 The global carbon market and the CDM under the Bonn agreement**

The size of the CDM, in terms of both volume of emission offsets and financial revenue, will depend on the total emission reductions required to meet the Kyoto Protocol targets, the comparative costs of achieving emission reductions under the different options provided for by the Protocol (domestic reduction of emissions, Joint Implementation (JI) and the CDM) and the availability of surplus credits under emissions trading ('hot air'). Within the CDM, the distribution across countries will be determined by the availability and cost of project options, as well as institutional factors, established investment linkages, perceptions of risk and other factors.

### **3.1 Emission reductions required to meet Kyoto commitments**

The emission reductions required of Annex B countries under the Kyoto Protocol are defined as the difference between business-as-usual emissions and the maximum emission levels specified in the Protocol. Table 1 shows estimates of the emission reductions required by the various Annex B Parties by 2010. Three different information sources are used: USDoE forecasts for CO<sub>2</sub> emissions from the energy

sector (which are used for the modelling in this paper); a compilation of the projections contained in National Communications submitted to the UNFCCC (Zhang); and baselines from a general equilibrium model (GTEM). In addition, the table shows the creditable amount of sinks under Article 3.4.

Figures for the required emission reductions in the USDoE energy projections are higher than those in the National Communications projections, and lower than GTEM modelling projections. This is to some degree due to a difference in the modelling approach.<sup>4</sup> The USDoE data are considered most appropriate for the purpose of this study, and are thus used as the principal set of projections of global emissions and reduction requirements.

The United States are projected to account for between half and three quarters of the total emission reductions required under the Kyoto Protocol. This is both because it is the largest emitter of greenhouse gases (GHGs) and because its emissions have increased steadily since 1990 and are expected to keep increasing. Implementing the Kyoto Protocol without the United States, which increasingly appears to be the most realistic scenario, means the demand in the global carbon market will be greatly reduced (table 1). Under USDoE projections, total emission reduction requirements of Annex B countries except the United States amounts to 1.1 Gt CO<sub>2</sub>/year, not taking into account 'hot air' and sinks credited under Article 3.4. In the United States by comparison, the projected overhang of emissions in 2010 over the Kyoto target level amounts to almost 2 Gt CO<sub>2</sub>/year.

The regional distribution of emission reduction requirements among the remaining Annex B countries varies strongly across projections. However, for the analysis of CDM demand under unrestricted emissions trading, the important parameter is the aggregate reduction requirement. Under USDoE projections, the required emission

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4 The nature of projections in the USDoE forecasts is that of 'best guesses' of future carbon dioxide emissions.

National Communications contain projections that have been officially endorsed by the respective governments. The projections can be judged to be over-optimistic for the EU (i.e., low projected emissions) and pessimistic for U.S. and EIT (higher than realistic business-as-usual emissions), reflecting the political expediency. Moe and Tangen (2000).

In general equilibrium models such as GTEM by contrast, pure 'business-as-usual' scenarios are constructed, which generally exclude the effect of current and planned climate related policies in the baseline projections, and therefore may overstate actual future emissions.



reductions of 1.1 Gt CO<sub>2</sub>/year for OECD Annex B countries except the United States – the expected 'net buyers' of emission offset credits – amount to 18 per cent of business-as-usual emissions in this group of countries.

**Table 1: Required emission reductions, relative to business-as-usual in 2010**

	Emission reduction requirements (comparison of alternative projections)			Sinks credits under Article 3.4 (forest management and agricultural soils)
Source	PET, based on USDoE energy sector forecast (CO <sub>2</sub> from combustion) a	Zhang (com- pilation of National Com- munications projections) b	GTEM (CGE model reference case) c	'Core elements' agreed on at COP6bis (‘Bonn agreement’) d
	Mt CO <sub>2</sub> /year	Mt CO <sub>2</sub> /year	Mt CO <sub>2</sub> /year	Mt CO <sub>2</sub> /year
European Union/Western Europe	572	106	550	-53 (-19 forests, - 34 agriculture)
Japan	271	260	290	-49 (-48 forests, -1 agriculture)
Other OECD Annex B, excluding USA d	257	220	425	-75 (-46 forests, - 29 agriculture)
Aggregate OECD Annex B (without US) – <i>excluding</i> sinks under 3.4, excluding hot air	1,100	586	1,265	-177 (-113 forests, - 64 agriculture)
Aggregate OECD Annex B (without US) – <i>including</i> sinks under 3.4, excluding hot air	923	409	1088	
EIT countries (hot air)	-1,166	-235	-1,074	-121 (-87 forests, - 34 agriculture)
Aggregate OECD Annex B (without US) – including sinks under 3.4, <i>including</i> full hot air	(-364)	53	(-107)	
<i>Memo: United States</i>	<i>1,962</i>	<i>1,555</i>	<i>2,490</i>	<i>-170</i> <i>(-103 forests, -</i> <i>67 agriculture)</i>

a Forecast CO<sub>2</sub> emissions from the energy sector. Source: US Department of Energy (2000). This data is used in PET (Pelangi's Emissions Trading model), used for modelling issues under negotiation and Indonesia's share in the CDM.

b Projected emissions of all greenhouse gases based principally on national projections submitted to the UNFCCC -- see Zhang (1999). Data source: CERT model, scenario 5, see Grütter (2000).

c Projected emissions of CO<sub>2</sub>, methane and nitrous oxide from ABARE's general equilibrium model – see Polidano et al. (2000). Data source: CERT model, scenario 9; see Grütter (2000).

d See UNFCCC 2001. Sinks data entered as negatives because these are credits for business-as-usual forest management activities, reducing the requirement for additional emission reductions. For agricultural soil sinks, 10% of the medium variant estimate of soil carbon storage has been used – see appendix.

e 'Other OECD Annex B' grouping includes Canada, Australia and New Zealand; as well as Norway and Switzerland except for the US Department of Energy (USDoE) data, where they are part of the 'Western Europe' region.

The Bonn agreement provides for crediting of carbon sequestration resulting from business-as-usual under Article 3.4 of the Kyoto Protocol, up to a specified cap for each country. For the 'net buyers' of emission credits, this amounts to 113 Mt CO<sub>2</sub>/year (table 1, last column). In addition, Article 3.4 provides for crediting of increases in carbon storage in agricultural soils. No limits have been specified for this category of sinks, and volumes are potentially high in some countries. Assuming that additional storage amounts to 10 per cent of the central estimate for soil carbon storage, this would amount to 64 Mt CO<sub>2</sub>/year (see also appendix 2). Combining the two categories, sink allowances under Article 3.4 are therefore estimated to lower the emission reduction requirements of net buying countries by 177 Mt CO<sub>2</sub>/year, or around 16 per cent.

In a number of countries, emissions are predicted to stay below Kyoto target levels even if no emission reduction measures are undertaken. This is the case in most economies in transition (EIT) countries, such as Russia, the Ukraine and a number of Eastern European countries. In these cases, the difference between business-as-usual emissions and Kyoto targets is termed 'hot air'. These surplus credits can be sold under emissions trading. According to some estimates, total hot air in the first commitment period may outweigh the Annex B emission reduction requirements if the United States do not participate (indicated by negative numbers in the second last row of table 1). Although there is considerable uncertainty about future economic developments and emissions, particularly in Russia and the Ukraine, it is likely that there will be a large amount of hot air.<sup>5</sup>

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5 Data from some other GE models, for example MIT-EPPA, imply very low amounts of hot air. We judge the underlying assumption that emissions in Russia and the Ukraine are going to increase steeply over the next ten years to be highly unlikely, and therefore do not present these estimates for comparison here.

Recent data for Russia shows that emissions have continued to decline and were just 62 percent of 1990 levels in 1997 (US Department of Energy 2000). In 1998 and 1999, energy consumption has not changed significantly (Moe and Tangen 2000), indicating that emissions are not growing. Moe and

### 3.2 Shares of the mechanisms

Annex B countries can meet their emission reduction obligations through a combination of the following actions:

- Domestic action to reduce emissions below business-as-usual
- Buying emission credits from other Annex B countries under emissions trading – in practice, buying surplus AAUs (hot air) from EIT countries
- Investing in Joint Implementation (JI) projects, again in EIT countries, and use the resulting Emission Reduction Units (ERUs) towards their targets
- Investing in emission reduction projects in developing countries under the CDM, or buying the Certified Emission Reductions (CERs) directly from a project participant.

The analysis here assumes full fungibility, i.e., emission credits from emissions trading, JI and the CDM can be used interchangeable to meet a country's Kyoto Protocol commitments. From this assumption, it follows that there will be a common international market price for emission credits (the 'quota price').<sup>6</sup> CDM projects are therefore in direct competition with emission reduction projects and policies in Annex B countries, and with supply of quota from EIT countries.

Under standard assumptions, our modelling results are that around one third of effective emission reduction requirements would be met through CDM projects, amounting to 296 Mt CO<sub>2</sub> per year. Domestic action in net quota buying countries – beyond accounting for sinks under Article 3.4 – would account for only around one sixth of reduction requirements, while emission credits from EIT countries would account for over half of the global carbon market – 43 per cent from hot air, and another 8 per cent from JI projects.

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Tangen (2001) estimate that Russia's quota surplus will be between 31 and 42 percent; the estimate used in PET is 31 percent for all of the Annex B countries of the former Soviet Union.

<sup>6</sup> The only exception are CERs from sinks projects in developing countries, which can only be used up to a certain level in each Annex B country, and will thus be traded in a separate market.

**Table 2: Share of mechanisms in meeting Annex B Kyoto Protocol commitments**

Mechanism	Mt CO <sub>2</sub> /year	Share in market
CDM	297	32%
Domestic abatement in net buying countries (Annex B OECD countries except United States)	149	16%
Joint implementation in EIT countries	78	8%
Sales of AAUs by EIT countries ('hot air') – modelling assumption	400	43%
Total	923	100%

Source: PET modelling, standard scenario.

Note: See text for assumption on hot air volume.

It should be noted that these estimates are sensitive to the assumption on supply of emissions quota from Russia and other EIT countries. Supply of emission credits from EIT countries will be a key factor in the global carbon market, and will affect the size of the CDM. Hot air will tend to be used first, as there is no cost involved in creating emission credits. As discussed above, it is possible that there will be enough hot air to meet all of the emission reduction requirements without the United States. However, there are a number of reasons why it is highly unlikely that all of available hot air will be sold in the first commitment period, and/or that most of Annex B demand will be met using hot air (see also Moe and Tangen 2000):

- **Banking:** Surplus CERs may be retained for use in future commitment periods. EIT countries are expected to make use of this facility to cover for subsequent commitment periods where actual emission reductions below business-as-usual may be required.
- **Constraining supply to increase prices:** As the largest potential supplier in the carbon market, Russia will have a degree of market power which may allow it to increase revenue by reducing the quantity of AAUs sold. This has been further

enhanced by the high amount of 3.4. forestry sinks allocated to Russia. If EIT countries coordinate their sales, constraining supply is even more effective.

- Avoiding crowding out of JI projects: EIT countries have an interest in expanding direct investment and cooperation in Joint Implementation (JI) projects with Europe, Japan and other countries. Flooding the market with AAUs may lead to a reduction in JI projects.
- Supplimentarity considerations: Although the provisions for supplimentarity in the Bonn agreement are weaker than previous proposals ('domestic action to constitute a significant element of the effort'), many net buying countries will not be politically willing to fulfil most of their emission reduction requirements by buying hot air, even if this were the cheapest option of fulfilling the letter of their commitment. Similarly, it is likely that a number of Annex B countries will try to ensure that there is a significant amount of technology transfer under the CDM.

Without more information on these factors, it is not possible to judge the amount of hot air that will actually enter the market. In this analysis, it is assumed that the amount of hot air in the market will be 400 Mt CO<sub>2</sub> per year, equivalent to just under one third of the total available projected surplus in emission credits.<sup>7</sup> This number was chosen to reflect the assumption that there will be a significant amount of hot air traded, but that there will still be room for domestic action, JI and the CDM. Sensitivity analysis on the hot air assumption is conducted in section 6.

Given supply of hot air, the CDM's share of the carbon trade market depends on the relative cost of achieving abatement in developing countries, compared with Annex B countries – both domestically in OECD Annex B countries and through JI. The lower the cost at which emissions reductions can be achieved in non-Annex B countries, relative to Annex B countries, the greater the share of the CDM in the global carbon market – see section 5 for sensitivity analysis on CDM supply assumptions.

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<sup>7</sup> Under US Department of Energy projections, when taking account of additional sinks credits allocated to EIT countries under Article 3.4 (see table 1).

### 3.3 CDM prices, volume and revenue

The analysis here estimates the size of global CDM at 296 Mt CO<sub>2</sub>/year, at a price of 0.90 \$/tCO<sub>2</sub>. Total after-tax revenue from CDM projects would then be \$ 1.3 billion over the first commitment period, which includes expenses for transaction costs and adaptation tax. Of the total CDM volume, 67 Mt CO<sub>2</sub>/year would come from sink projects – assuming that the OECD Annex B countries use their full allocation of 1 per cent of assigned amounts, and that EIT countries as net sellers of quota do not invest in CDM sink projects<sup>8</sup>.

**Table 3: CDM volume, prices and revenue**

	<b>PET standard scenario</b>
Total CER sales (Mt CO <sub>2</sub> /year)	297
Of which:	
CERs from non-sink projects	230
CERs from sink projects <sup>a</sup>	67
International quota price (\$US/t CO <sub>2</sub> )	0.90
Total CDM revenue over first commitment period (\$US million) <sup>b</sup>	1,332
Total adaptation tax over first commitment period (\$US million) <sup>b</sup>	27

Source: see table 3.1.

a Sink CERs limited to 1 per cent of assigned amounts of participating OECD Annex B countries. EIT countries (net sellers of quota) are assumed not to use the quota of sink CERs they are allowed to purchase.

b Revenue calculation assuming same price for sink and non-sink CERs. In practice, prices for sink CERs may be lower, leading to lower overall CDM revenue.

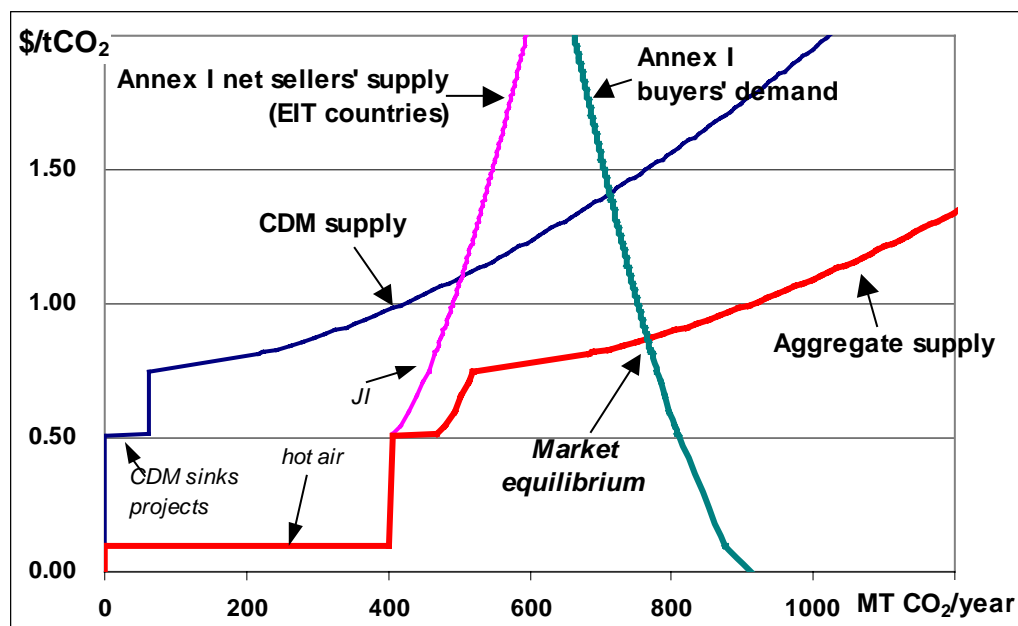
Global supply of and demand for emission credits as a function of quota prices is plotted in figure 1. The Annex B demand curve has been derived from data on the magnitude of emission reductions required by Annex B OECD countries excluding the United States (the net buyers of credits) in order to meet their Kyoto commitments and data on the cost of domestic action in these countries. The supply of CERs reflects the

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<sup>8</sup> If transaction costs are low, however, EITs could try to substitute AAUs by CDM sinks credits and sell the surplus AAUs.

collective marginal abatement cost (MAC) curves of developing countries across all project types, transaction costs included. Sale of emission credits by Annex B EIT countries will depend on the amount of hot air put on the market (horizontal part of the supply curve), as well as the cost of effecting actual emission reductions under JI. The aggregate supply is simply the addition of supply from both the CDM and Annex B net sellers at any given price.<sup>9</sup>

**Figure 1 Supply and demand in the global carbon market**



Source: PET model calibration, standard scenario – CDM supply.

The estimates for the global carbon price and CDM volume in this analysis are substantially lower than most that were previously in the discussion (see for example Vrolijk 2000, Polidano et al. 2000, Zhang 1999). This is primarily due to the fact that implementation of the Kyoto Protocol without the United States is assumed and extra sinks are included according to the Bonn agreement. In addition, the PET model generally leads to estimates of carbon prices that are at the lower end of the range when compared to other modelling results. Reasons include that projected baseline emissions, and therefore required emission reductions are lower than in some other models, and

<sup>9</sup> From the figure it can be seen that the quota price is around 0.90 \$/tCO<sub>2</sub>, and around \$ 1.40/tCO<sub>2</sub> if the CDM had no competition from Annex B sellers.

that extra abatement under the CDM in the form of and low cost options resulting from a reduction in gas flaring are taken into account.

So far, speculative carbon trades have been effected at around 0.60 and 3 \$/tCO<sub>2</sub> (2-10 \$/tC, see Natsource 2001). The relatively low prices reflect several factors:

- Uncertainty about the entry into force of the Kyoto Protocol.
- The relatively cheap options for abatement action are being utilized first.
- The variable quality of the credits – many of which would clearly not satisfy Kyoto rules.

Prices for emission reduction units in high-quality programs like the Prototype Carbon Fund (PCF) and the Dutch ERUPT program (JI only) are much higher, at around 5 \$/tCO<sub>2</sub> (PCF) and 5-8 \$/tCO<sub>2</sub> (ERUPT) respectively. The higher prices reflect the relatively high outlay on capacity building in these projects, which in turn reflects the currently limited institutional capacity for CDM project implementation. ‘Best guess’ estimates from before the Bonn agreement have put the world market price for ‘Kyoto-proof’ carbon credits at around 2-3 \$/tCO<sub>2</sub> (e.g. Vrolijk/Grubb 2000). However, such estimates assumed that the Protocol is implemented with the participation of the United States.

After the Bonn agreement, a ‘low demand, low price’ carbon market scenario such as the one presented here appears likely, given that

- The United States are unlikely to participate in the first commitment period, and ratification of the Protocol by a number of other countries (for example Canada and Australia) cannot be taken for granted.
- Kyoto implementation rules such as the crediting of sinks under Article 3.4 are effectively reducing country targets under the Protocol.
- Domestic policies aimed at reducing emissions are already in place, particularly in the European Union, and will tend to reduce demand for emission offsets in the international carbon market.



- On the supply side, it is increasingly likely that Russia and other EIT countries will have significant amounts of surplus quota (hot air) available, and implementation rules have not put limits on the sale of these credits.
- The inclusion of an amount sinks projects under the CDM will provide a cheap source of CERs, compared to most energy sector projects.

However, if stringent targets are negotiated for the second commitment period before the first commitment period starts, prices could rise considerably as first commitment period supply will be reduced due to banking.

At the time of writing there are no published modelling estimates of quota prices and trade volumes under the Bonn agreement, or more generally for implementation of the Kyoto Protocol without United States participation, so direct comparison across models is not possible at this stage.

### **3.4 Global distribution of CDM**

In an analysis based on relative marginal abatement costs, the distribution of CDM projects between countries depends on the relative availability and cost of abatement options. Given the assumption that transaction costs are the same across developing countries, and abstracting from country specific factors such as the policy environment, quality of institutions, risk, and established international investment relations, a country's actual share of the CDM market may be significantly larger or smaller than estimated here, depending on how conducive its policy and institutional environments are. Only the distribution of non-sink projects is modelled here, as it is not possible at this stage to evaluate how the limited quota of sink CERs under the Bonn agreement is likely to be allocated.

Supply-side fuel efficiency and fuel switching projects, particularly in the area of electricity generation, tend to offer the largest abatement potential in the energy sector (Austin and Faeth 1999); in many cases these options also involve relatively low emission reduction costs per unit. Projects that increase the efficiency of fossil fuel extraction and distribution (e.g. reduction of gas flaring, reduction of transport losses) are also usually cheap and generate high volumes of emission reduction units. Energy

efficiency projects on the demand side can be very cheap, but generally the potential is smaller than for supply side options.

Countries that rely heavily on coal for their energy needs and/or countries where the major energy users (e.g. power plants, heavy industry) are relatively inefficient tend to have the greatest potential for large and cheap CDM projects, if they have access to low-carbon alternatives such as natural gas or hydro power. Countries with high levels of emissions from oil and gas production also tend to have significant low-cost emission reduction potential. In the absence of any barriers to CDM investment, countries with these characteristics can expect a relatively larger share of the CDM market.

**Table 4: Global distribution of non-sink CDM**

	PET modelling results		For comparison	
	CER sales, excluding sinks projects (Mt CO <sub>2</sub> /year)	Share of global non-sinks CDM volume	Share of non-Annex B emissions at 2010 (CO <sub>2</sub> from combustion)	Share of non-Annex B GDP at 2010
China	120	52%	41%	23%
India	29	12%	11%	8%
Indonesia	5.6	2.5%	2.0%	1.9%
Other Asian countries	24	10%	16%	28%
Middle East	18	8%	12%	7%
Africa	25	11%	8.0%	7.3%
Brazil	1.3	0.6%	4.0%	13.3%
Other Latin American countries	7	3.2%	7.0%	11.3%
Total	230	100%	100%	100%

Source: CDM volume – PET modelling, standard scenario; 2010 emissions and GDP projections: US Department of Energy 2000.

China relies heavily on coal, and has a large number of relatively old plants with low energy efficiency. Emissions per unit of output are comparatively high, which is evident in the discrepancy between China's share in non-Annex B emissions and its share in GDP. While significant progress has been made in increasing demand-side energy efficiency disproportionately large opportunities remain, especially on the supply side (Zhang 2000, Michaelowa et al. 2000). This is reflected in the modelling results of the

share of the CDM: China is projected to attract around half of the total CDM volume, higher than its share of projected non-Annex B emissions by 2010 and more than double its projected share in non-Annex B GDP at 2010 (table 4). India is also projected to attract a significant share of CDM projects, again associated with the predominance of coal and relatively low efficiency in the energy sector (i.e., supply-side efficiency); in India's case however the potential for gas flaring projects is relatively low, so that overall, India's estimated share in the CDM is commensurate with its share in carbon dioxide emissions.

Indonesia's projected share of 2.5 per cent in the CDM is slightly higher than its share in emissions. At low international market prices – such as in this analysis –, the bulk of emission reductions is projected to be achieved in the reduction of emissions from gas flaring – that is, using gas that is currently burned off as a side product of oil and gas extraction for electricity generation. Similarly, a large share of CERs generated in the Middle East and Africa is projected to come from gas flaring projects.

In Brazil and many other Latin American countries, options for low-cost, large-scale CDM projects in the energy sector are scarce. Their estimated share in global non-sink CDM is therefore smaller than their share in emissions, and much smaller than their share in GDP. Hydroelectricity is the predominant source of energy, and emissions per unit of output are already comparatively low. Aside from deforestation, carbon dioxide emissions come mainly from sectors such as transport, where emission reduction options are limited and expensive. As a result, Brazil's projected share in the CDM is smaller than its share in GHG emissions (even when excluding emissions from deforestation, as in table 4). This result would be even stronger if it were not for the inclusion of a limited amount of sinks under the CDM, of which Brazil is thought to attract a significant share – along with other Latin American and tropical Asian countries, and China.

Low market prices for carbon offsets credits will mean that only the lowest cost options for emissions reductions have a chance to be implemented as CDM projects in the first commitment period. Transaction costs may constitute a sizeable portion of total project costs; and since intense competition between potential CDM host countries is likely, countries with lower transaction costs will have advantages. The quality of domestic institutions and procedures, internal political stability and efforts to market CDM

projects to investors will also be important for individual countries to secure their share in the CDM market.

### **3.5 Sequestration projects under the CDM**

The Bonn agreement provides for a limited amount of afforestation and reforestation projects under the CDM in the first commitment period. Annex B countries can use CERs from sequestration (or 'sink') projects under the CDM up to a maximum of 1 per cent of their base year emissions in each year of the commitment period. For the OECD countries except the United States – that is, the anticipated buyers of emissions quota in the international market –, this amounts to 67 Mt CO<sub>2</sub>/year. This is an approximation of the expected size of the market for CDM sink credits; it is relatively small compared to potential supply. A recent conservative estimate puts the potential supply of CERs from afforestation and reforestation projects in developing countries at between 40 to 100 Mt CO<sub>2</sub>/year in the first commitment period (Vrolijk and Grubb 2000, p. 8).

The agreement reached at COP6bis leaves open the possibility for net selling countries of emission quota to also invest in CDM sink projects, use the resulting CERs towards achieving their domestic target and in turn increase their sales of quota in the international market by an equivalent amount. The total allocation of sink CERs that could be bought by EIT countries is 54 Mt CO<sub>2</sub>/year. A profit could be made by 're-selling' sink CERs if the marginal cost for CERs generated from sink projects is lower than the prevailing price in the international carbon market. However, since there will be significant amounts of hot air in the largest EIT countries, this analysis assumes that EIT countries do not invest in sink CDM projects.<sup>10</sup>

It is not clear at this stage how the limited market volume for sequestration projects will be distributed geographically. Perceivably there will be competition between non-Annex B countries to host sequestration projects, primarily in order to attract investment; while Annex B investors would seek out the lowest cost project options. This would tend to concentrate sinks projects in countries where implementation costs are lowest. However, experience with prototype sinks projects may become a decisive factor for the location of sinks projects under the CDM, at least in the first commitment

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<sup>10</sup>It is conceivable that some Eastern European countries will be net buyers of quota and thus may use their sink CER quota toward their own emissions target. The magnitudes involved here however are likely to be small.

period. This would tend to put Latin American countries in a more favourable position, as they are hosting the bulk of sequestration projects to date. Yet another possibility is that there will be some form of negotiated allocation of quota for implementing sinks projects under the CDM among developing countries.

Table 5 presents examples of the potential magnitude of CDM sinks projects under alternative geographical distributions, compared to the estimated volume of non-sinks projects.

**Table 5: Distribution and magnitude of sink CERs – examples**

	<b>Allocation based on potential for plantations a</b>				<b>Memo: Non-sinks projects</b>
	<b>Trexler and Haugen 1995 <sup>a</sup></b>		<b>Niles et al. 2001 <sup>c</sup></b>		<b>PET modelling</b>
	<b>Share</b>	<b>Mt CO<sub>2</sub>/year given global cap</b>	<b>Share</b>	<b>Mt CO<sub>2</sub>/year given global cap</b>	<b>Mt CO<sub>2</sub>/year</b>
China	(37%) <sup>b</sup>	24.7	7%	4.5	120
India	5.6%	3.8	1.3%	0.9	29
Indonesia	25%	17.0	0.7%	0.4	5.6
Other Asian countries	12%	8.3	22%	14.6	24
Middle East	0%	0.0	0%	0.2	18
Africa	2.4%	1.6	13%	8.8	25
Brazil	15%	9.9	33%	21.8	1.3
Other Latin American countries	2.5%	1.7	24%	15.8	7.3
Total	100%	67	100%	67	230

a Shares in non-Annex B potential carbon storage in new plantations using Trexler and Haugen (1995). Author's calculations based on data for plantation potential in hectares and average carbon density.

b China estimate substituted from shares provided in Polidano et al. 2001 (data based on projections for new plantings).

c Shares in non-Annex B potential carbon storage through reforestation using Niles et al. 2001.

If sinks projects were distributed in line with the estimated potential for carbon sequestration in new plantations – reflecting the availability and suitability of land –

then the bulk of sinks projects would be implemented in the tropical countries of Latin America and Southeast Asia, and possibly in China. However, available estimates vary greatly in the estimation of potential in particular countries; for example, Indonesia's potential for carbon plantations has variously been estimated to be very large or relatively small (see table 5). The IPCC special report on land use, land use change and forestry (IPCC 2000) concluded that to date there are no reliable estimates of the geographical distribution of potential sinks projects. A lot will depend on the final eligibility and implementation rules for sinks projects, as well as on the domestic policy environment in potential host countries.

Looking at the magnitude of sinks projects in terms of CERs generated compared to other types of CDM projects, it becomes obvious that sinks projects will probably be most significant in Latin American countries. In our two examples, Brazil would sell around 10 and 22 Mt CO<sub>2</sub>/year of CERs from sinks projects respectively, compared to just 1.3 Mt CO<sub>2</sub>/year from other projects. This reflects both the abundance of opportunities in the forestry sector, and the lack of options for CDM projects in the energy sector. Sinks projects may perceivably also outweigh non-sinks projects in some South-East Asian countries, exemplified in our analysis by Indonesia – in this case, the reason is the possibly large potential for reforestation, rather than a dearth of project options in other sectors.

In China there may be significant potential for afforestation and reforestation projects. However, CERs from these projects would be minor compared to what may be achievable in the energy sector even if China secured a large share of the global market of 67 Mt CO<sub>2</sub>/year of CERs from sinks projects. Most Middle Eastern and African countries, as well as India have very low estimated potential for carbon sinks plantations.

Finally, it is worthwhile noting that the cap on the use of sink CERs under the Bonn agreement is likely to lead to a separation of markets for sink and non-sink CERs. While there are no quantitative limits on the use of CERs from non-sink projects toward Annex B emission reduction targets, the global demand for sinks projects is limited to a predetermined level. If that amount of sink projects can be implemented at a lower marginal cost than the prevailing price for other types of emission credits, then sink CERs will tend to be traded at lower prices. This situation of a 'buyer's market' is likely, given that demand is capped at a relatively low level, that there is high potential

supply, and that sink projects tend to have lower costs per unit of carbon dioxide than most energy sector abatement options.

## **4 Sensitivity analysis on CDM supply**

Estimates of the potential for and cost of CDM projects are subject to considerable uncertainty. Sensitivity analysis on implementation and transaction costs, as well as the effects of rules on baselines and additionality illustrates the changes in estimated size of the CDM, quota prices and overall CDM revenue. The analysis shows that the cost of generating CERs could change the size of the CDM and the international quota price considerably. A key insight is that shifts in the CDM supply curve are likely to have only a small impact on CDM revenue, as changes in the quantity of CERs sold globally and the quota price achieved tend to cancel each other out.

### **4.1 CDM implementation and transaction costs**

Estimates of emission abatement costs are still uncertain, and the parameters used in this analysis – or any other top-down modelling study – should not be interpreted as a reliable guide to actual abatement potential and costs, but primarily as an illustration of the differences between countries. While the basic tenet, namely that emission reductions in developing countries tend to be achievable at lower cost than in industrialized countries, seems robust, the magnitude of these differences is less certain. Regarding transaction costs, there is little empirical evidence, and no possibility of estimation. Transaction costs will depend on the CDM implementation rules to be agreed on, and on the efficiency of procedures and institutions at a national level. Consequently, the true marginal costs for any given level of abatement under the CDM may well turn out to be quite different from those assumed in the standard modelling scenario.

For sensitivity analysis on the cost of implementing projects, transaction costs for CDM projects are increased and lowered compared to the standard assumptions, and simultaneously the slopes of developing countries' marginal abatement cost curves are varied from the standard calibration. This amounts to shifting the marginal abatement cost curves (which translates to the CDM supply curve) downward/upward. The changes are done homogeneously across developing country regions; all other

assumptions, including the volume of CERs from sinks projects and sales of hot air, are unchanged.

**Table 6: Higher and lower implementation and transaction costs for CDM projects**

	<b>Standard scenario</b>	<b>High CDM costs</b>	<b>Low CDM costs</b>
Share of CDM in global carbon market	32%	25%	40%
Total sales of non-sink CERs (Mt CO <sub>2</sub> /year)	230	166	306
International quota price (\$US/t CO <sub>2</sub> )	0.90	1.18	0.62
Total CDM revenue over first commitment period (\$US million) <sup>a</sup>	1,332	1,376	1,149

Source: PET modelling. Changes in parameters: CDM transactions costs 0.75 \$/tCO<sub>2</sub> (standard), 1.00 \$/tCO<sub>2</sub> (high), 0.50 \$/tCO<sub>2</sub> (low). Slopes of marginal abatement cost curves doubled (high) and halved (low).

<sup>a</sup> Revenue calculation includes 67 Mt CO<sub>2</sub>/year of sink CERs, assuming same price for sink and non-sink CERs.

Changing these cost assumptions has significant effect on the modelling result for the size of the CDM, and also the international quota price (table 6). The quantity of CERs sold is lower if costs are higher, with more abatement undertaken in net quota buying countries and through JI (the sales volume of hot air is assumed fixed at the standard level). However, this forces a move up along the marginal cost curves in all countries, resulting in an increase in the price paid for emission offset credits, including CERs.

In terms of CDM revenue, the two effects largely cancel each other out. In fact, under the parameters in this analysis CDM revenue would actually increase as a result of higher CDM costs. This is a result of the relatively inelastic demand for emission offset credits from Annex B countries, reflecting steeply increasing costs as more abatement is undertaken in industrialised countries. The result also depends on the assumption that supply of credits from hot air remains unchanged under different CDM cost scenarios.

Finally, if CDM transaction costs were significantly higher than assumed in this analysis, it is likely that transaction costs could make the CDM uncompetitive as a mechanism for meeting Kyoto commitments. There is a particular danger of this if Annex B demand is turns out to be even lower than assumed here, which would push the international quota price downward (see below).



## 4.2 Baseline and additionality rules

CDM project potential and project costs are also affected by the type of baseline used. For example, developing countries with domestic fossil fuel resources may be able to claim more emission credits for any given project by asserting that the use of fossil fuels, especially that of high-emission fuels such as coal, would be increased under business-as-usual. Another issue currently being debated is whether or not ‘growth’ baselines will be allowed under the CDM, i.e., whether the business-as-usual assumption will allow for increased emissions from any particular activity. If the assumption that emissions would grow under a business-as-usual scenario were allowed then projects for emissions avoidance would result in more CERs. Current negotiations tend to accept growth baselines, especially to encourage the commitment of African states.

In the modelling context, more ‘generous’ baseline rules translate into flatter marginal abatement cost curves, as any given project will create more CERs, at the same cost. Sensitivity analysis using curves that yield 30 per cent more abatement at the same marginal cost shows that the effect of baseline rules on the total size of the CDM is likely to be relatively small; again, the quantity and price effects are countervailing (table 7).<sup>11</sup>

**Table 7: ‘Generous’ baselines and no-regrets projects**

	<b>Standard scenario</b>	<b>Generous baselines</b>	<b>No-regrets potential</b>
Share of CDM in global carbon market	32%	33%	34%
Total sales of non-sink CERs (Mt CO <sub>2</sub> /year)	230	239	246
International quota price (\$US/t CO <sub>2</sub> )	0.90	0.86	0.83
Total CDM revenue over first commitment period (\$US million) <sup>a</sup>	1,332	1,316	1,301

Source: PET modelling. Changes in parameters: ‘Generous baselines’ - slopes of marginal abatement cost curves 50 per cent flatter. ‘No-regrets potential’ – additional supply of 100 Mt CO<sub>2</sub>/year incurring only transaction costs.

<sup>a</sup> Revenue calculation includes 67 Mt CO<sub>2</sub>/year of sink CERs, assuming same price for sink and non-sink CERs.

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<sup>11</sup> The main reason for the small impact of changes in the slopes of the marginal abatement cost curves is that in our analysis, transaction costs account for a relatively high proportion of the price of CERs.

A separate but related issue is additionality rules and the potential for ‘no-regrets’ projects under the CDM. ‘No-regrets’ denotes projects which reduce emissions and at the same time lead to financial savings – the cost of producing CERs under such circumstances is therefore negative. Such options can exist if there are barriers to investment, for example. Whether ‘no-cost’ projects will be eligible under the CDM depends on how strictly and comprehensively the investment additionality test will be applied (see Sugiyama and Michaelowa 2001, and Langrock et al. 2001). In the standard analysis in this paper, it is assumed that there are no no-regrets. However, the possibility of ‘fast-tracking’ of small CDM projects, as provided for under the Bonn agreement, may mean that some smaller projects will not have to fulfil the investment additionality criterion.

No-regrets projects can be modelled by assuming a certain supply of CERs that incur only transaction costs, but no implementation costs, shifts the aggregate CDM supply curve outward. Including 100 Mt CO<sub>2</sub>/year of CER supply from no-regrets projects is estimated to increase the total size of the CDM by just 16 Mt CO<sub>2</sub>/year, as these cheaper options displace the more expensive projects. The international quota price would be lowered, resulting in slightly lower revenue from CDM projects overall. Again, the overall impact is relatively small due to the very low price in the standard scenario.

The analysis here abstracts from the inter-regional effects that different baseline rules and additionality requirements would have. Impacts are likely to differ significantly between countries, depending for example on the ‘threat potential’ of individual countries for high emission baselines, and on the availability of no-regrets project options that are allowable under the Kyoto implementation rules.

## **5 Sensitivity analysis on CDM demand**

The effective demand for emission offsets from CDM projects will depend on the magnitude of the emission reductions required in OECD Annex B countries relative to business-as-usual, as well as the cost and supply of credits generated using competing mechanisms. Sensitivity analysis shows that variations in the projected emissions growth path of Annex B countries, the crediting of carbon sequestration in agricultural soils under Article 3.4 and the amount of hot air entering the market all have the potential to greatly diminish or increase the size of the CDM. Prices would move in the same direction, resulting in an amplified effect on CDM revenue. The greatest effect on

CDM demand would be expected if the United States participated in the Kyoto Protocol.

### **5.1 Business-as-usual emissions and abatement costs in OECD Annex B regions**

Required emission reductions depend on the magnitude of business-as-usual emissions in OECD Annex B countries over the commitment period 2008–12. Because the Kyoto commitments are framed as absolute targets, even relatively small changes in the emissions growth path can have strong effects on the absolute size of the emission reduction requirement, and therefore demand for emission offsets from the CDM. In our example, we assume that emissions in the net quota buying countries (OECD Annex B countries minus United States) are 3 per cent higher/lower at 2010 than in the standard scenario. These are relatively small variations<sup>12</sup>; by comparison, the US Department of Energy's (2000) high and low growth projections put emissions for this group of countries around 6 per cent higher/lower than under the standard set of projections.

The 3 per cent change in business-as-usual emissions during the commitment period translates into a 20 per cent change in the required emission reductions. Assuming that supply of surplus emissions quota (hot air) from EIT countries remains unchanged at 400 Mt CO<sub>2</sub>/year, the effect on the size of the CDM would be sizeable (table 8). Under the high growth scenario, the CDM is estimated to account for almost half of the (larger) emissions quota market, compared to just under one third under the standard scenario. By contrast, if future Annex B emissions growth is low there may be very little effective demand for non-sink CDM projects. Emission quota prices are also estimated to vary significantly, compounding the effect on CDM revenue.

In reality, it would be plausible that higher or lower emissions reduction requirements would be offset to some degree by increased or reduced sales of hot air from EIT countries. Expanding supply in response to increased demand, or reducing supply to uphold prices in the opposite case could be part of a revenue increasing strategy by quota selling Annex B countries. In this case, the effect on the CDM would be less pronounced than in the analysis here.

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<sup>12</sup>The average annual growth rate of carbon dioxide emissions between 1997 and 2010 for this group of countries is 0.8 per cent in the standard scenario, compared to 0.6 and 1.1 per cent in the high and low scenario respectively.

**Table 8: Higher and lower emissions growth, and lower abatement costs in Annex B countries**

	Standard scenario	High Annex B emissions growth	Low Annex B emissions growth	High innovation: lower abatement costs in Annex B
Emission reductions required in Annex B countries	923	1103	744	923
Share of CDM in global carbon market	32%	48%	16%	30%
Total non-sink CER sales (Mt CO <sub>2</sub> /year)	234	378	81	210
International quota price (\$US/t CO <sub>2</sub> )	0.90	1.05	0.79	0.83
Total CDM revenue over first commitment period (\$US million) <sup>a</sup>	1,332	2,316	567	1,127

Source: PET modelling. Changes in parameters: High/low emissions growth - baseline emissions in Annex B countries 3 per cent higher/lower at 2010 than under the standard scenario. High innovation case – slope of OECD Annex B marginal abatement cost curves 50 per cent flatter. All other assumptions unchanged (in particular, supply of hot air 400 Mt CO<sub>2</sub>/year).

<sup>a</sup> Revenue calculation includes 67 Mt CO<sub>2</sub>/year of sink CERs, assuming same price for sink and non-sink CERs.

If the cost of reducing emissions in OECD Annex B countries below business-as-usual is lower than estimated – for example because advanced emission reduction technologies become available more cheaply than assumed –, then more abatement will be undertaken domestically and demand for CERs will be dampened. In a ‘high innovation’ scenario, the slopes of the cost curves for domestic abatement are halved. While this represents a significant change in assumptions, the effect on the CDM is relatively small. This is because domestic abatement in the quota buying countries accounts for only a small market share, and costs increase steeply compared to the whole of the developing world even under the sensitivity scenario.

## **5.2 Credits for sequestration in agricultural soils under Article 3.4**

Allowances for sequestration under Article 3.4 of the Protocol, as agreed on at COP6-bis in Bonn, directly reduce countries’ emission reduction tasks. While the Bonn agreement specifies a ceiling for the crediting for sequestration in managed forests (113

Mt CO<sub>2</sub>/year), no such quantitative cap was put on the crediting of sequestration in agricultural soils. There is considerable uncertainty about the scope for additional sequestration in agricultural soils; however, estimates have shown that the potential may be very large (see Sampson and Scholes 2000, and appendix).

In the standard scenario it is assumed that 10 per cent of the eligible soil area sequester a medium amount per ha by the first commitment period, amounting to 64 Mt CO<sub>2</sub>/year. The proportion of agricultural land that is managed for carbon storage will vary greatly between countries and might be significantly higher than 10 per cent in aggregate. To illustrate the potential impact, sensitivity analysis is conducted where emission credits from agricultural sinks are trebled, to 339 Mt CO<sub>2</sub>/year, representing 30 per cent of soil area.

The estimated impact on the carbon market and the CDM is similar to that in the ‘low business-as-usual emissions growth’ scenario above, with the size of the CDM reduced by almost half as a result of higher crediting of sinks under Article 3.4. While this analysis – just as the assumption for agricultural soil sinks in the standard scenario – is purely illustrative, it shows that the CDM, and therefore developing country involvement in the first commitment period, is highly contingent on the implementation rules for the Kyoto Protocol, and in particular crediting for sinks.

**Table 9: Higher credits for sequestration in agricultural soils under Article 3.4**

	<b>Standard scenario</b>	<b>High sequestration rates from agricultural soils</b>
Emission reductions required in Annex B countries	923	797
Share of CDM in global carbon market	32%	24%
Total non-sink CER sales (Mt CO <sub>2</sub> /year)	234	127
International quota price (\$US/t CO <sub>2</sub> )	0.90	0.81
Total CDM revenue over first commitment period (\$US million) <sup>a</sup>	1,332	773

Source: PET modelling. Changes in parameters: Soil area earning credits under Article 3.4 is 30 per cent of eligible land and sequestration potential per ha. is derived from the medium estimate (contained in appendix), compared to a credit-earning soil area of 10 per cent in the standard scenario. Agricultural soil sink credits amount to 192 Mt CO<sub>2</sub>/year (64 Mt CO<sub>2</sub>/year in the standard scenario).

<sup>a</sup> Revenue calculation includes 67 Mt CO<sub>2</sub>/year of sink CERs, assuming same price for sink and non-sink CERs.

### **5.3 Quota sales from EIT countries (hot air)**

Sales of surplus quota (hot air) from Russia and other economies in transition are likely to be a major factor in global carbon markets. As described above, the total volume of hot air available could be larger than the combined emission reduction requirements of the countries implementing the Kyoto Protocol; at the same time, for a variety of reasons we would expect that not all of these emissions quota will enter the carbon market in the first commitment period.

The Bonn agreement does not contain an effective limit on sales of surplus quota, beyond the ‘commitment period reserve’ which precludes overselling. Since there is no cost involved in generating these quota and transaction costs will be extremely low, hot air will be competitive at any quota price level, and tend to be used first by buyers of emission quota because of the cost advantage over other options. Consequently, how much hot air will enter the market will largely be determined by the suppliers unless there is a (unlikely) concerted effort by buyers to retire hot air from the system. Supply decisions will depend on a host of factors, the detailed analysis of which goes beyond the scope of this paper. It is likely that Russia and Ukraine, the countries which have by far the highest level of hot air, will try to form a cartel to maximise revenue. Institutional failures in these countries could however lead to a suboptimal strategy, selling away hot air quickly at low prices. Moreover, the impact of second commitment period targets on supply decisions should not be underestimated.

To illustrate the effect of hot air supply on the CDM, scenarios where the hot air sales volume is halved (to 200 Mt CO<sub>2</sub>/year) and increased by half (to 600 Mt CO<sub>2</sub>/year) are presented in table 10. As in the case of higher or lower emissions growth, the estimated impact on the demand for CERs is considerable – lower hot air sales would mean a boost for the CDM, higher volumes could considerably shrink it. In this example, CDM revenue is approximately doubled in the ‘low hot air’ case, and reduced to less than half if hot air sales are high. It is not inconceivable that supply of hot air could be expanded to the point where it accounts for the vast majority of quota sales at very low prices, largely crowding out the CDM. Under such a scenario, it is likely that only ‘demonstration projects’ would be implemented in the first commitment period, rather than commercially driven CDM projects.

**Table 10: Lower and higher sales volumes of hot air**

	<b>Standard scenario</b>	<b>Low hot air sales volume</b>	<b>High hot air sales volume</b>
Share of CDM in global carbon market	32%	50%	14%
Total sales of non-sink CERs (Mt CO <sub>2</sub> /year)	230	390	60
International quota price (\$US/t CO <sub>2</sub> )	0.90	1.07	0.78
Total CDM revenue over first commitment period (\$US million) <sup>a</sup>	1,332	2,443	494

Source: PET modelling. Changes in parameters: Sales of excess quota from EIT countries (hot air) 200/600 Mt CO<sub>2</sub>/year (low/high case); standard scenario: 400 Mt CO<sub>2</sub>/year.

<sup>a</sup> Revenue calculation includes 67 Mt CO<sub>2</sub>/year of sink CERs, assuming same price for sink and non-sink CERs.

## **5.4 US participation**

The withdrawal of the United States from the Kyoto has greatly weakened the effect of the Protocol on global emissions, as the United States accounts for between half and two thirds of projected Annex B emission reduction requirements compared to business-as-usual (see table 1). Due to the high reduction target relative to business-as-usual emissions, the United States would rely heavily on buying emission credits, including from CDM projects. In international emissions trading, the United States would be the single largest buyer of credits. Not having the largest source of demand for emissions quota on board means a much smaller CDM than would otherwise be the case.

In this analysis, using the emissions projections and sinks credits detailed in table 1, Annex B required emission reductions would be three times as high with the United States compared to without. Total CER sales are estimated almost five times higher than in the standard scenario without US participation, and the CDM share in the market would be significantly higher due to the assumption that supply of hot air is the same as in the scenario without US participation (table 11). The quota price is estimated substantially higher, reflecting higher marginal costs of abatement, as the lowest cost options to reduce emissions are exhausted and more expensive projects become viable. The combination of higher CDM volumes and higher prices means that estimated overall CDM revenue is an order of magnitude higher if the US participated. The volume of CDM projects in the forestry sector would also be larger, as the United States could make use of their allocated quota of crediting for investment in sinks projects.

As in other scenarios, the effects on the CDM depend to an important degree on the supply decisions by EIT countries. However, even if all of the surplus emission credits that are estimated to be available were sold in the first commitment period, this would fall far short of total Annex B demand if the United States implemented the Kyoto Protocol. In this hypothetical case, the share of the CDM in the global carbon market is estimated at one third, approximately the same as in the standard scenario; however the overall market is much larger and the quota price significantly higher (table 11, rightmost column). This shows that US participation in implementing the Kyoto Protocol would provide the chance for a significant amount of CDM projects to be implemented, irrespective of adverse demand side factors.

**Table 11: US participation in implementing the Kyoto Protocol**

	Standard scenario	With US participation	With US participation – maximum hot air sales <sup>a</sup>
Emission reductions required in Annex B countries	923	2715	2715
Share of CDM in global carbon market	32%	51%	33%
Total sales of non-sink CERs (Mt CO <sub>2</sub> /year)	234	1327	829
International quota price (\$US/t CO <sub>2</sub> )	0.90	2.63	1.63
Total CDM revenue over first commitment period (\$US million) <sup>b</sup>	1,332	18,296	7,261

Source: PET modelling. Changes in parameters: Participation of the United States in the Kyoto Protocol; BAU emission projections and sink credits as in table 1.

a Hot air sales of 1166 Mt CO<sub>2</sub>/year (full estimated volume), compared to 400 Mt CO<sub>2</sub>/year in the standard scenario.

b Revenue calculation includes 128 Mt CO<sub>2</sub>/year of sink CERs with US participation (67 Mt CO<sub>2</sub>/year in the standard scenario), assuming same price for sink and non-sink CERs.

## 6 Conclusion

The Bonn agreement means the aggregate effective emission reduction commitment by Annex B countries is relatively small, due to the withdrawal of the United States and crediting of sequestration under Article 3.4 of the Kyoto Protocol. The global carbon



market in the first commitment period will likely be characterised by low demand and low prices. Although the potential role for the CDM is seriously diminished, a significant amount of CDM projects in developing countries could still be achieved – depending on international market factors such as quota supply from Russia, the design of rules for CDM project implementation and the degree of stringency of second commitment period targets.

Low market prices for carbon offsets credits will mean that only the lowest cost options for emissions reductions have a chance to be implemented as CDM projects in the first commitment period. In these market conditions, transaction costs can amount to a significant share of total project costs; consequently it is important to design implementation rules in a way that ensures transaction costs for CDM projects are low, thus keeping the CDM competitive. Intense competition between developing countries to attract CDM investments is likely, and the quality of domestic institutions, internal political stability and efforts to market CDM projects to investors will be crucial for individual countries to secure their share in the CDM market. Experience from the AIJ pilot phase leads us to be sceptical about the potential of many developing countries to participate in a low-cost, efficient CDM.

On the demand side, there are a number of factors which could further reduce demand for emission offsets and thereby reduce the size of the CDM, or even preclude commercially driven CDM projects completely. Key factors that could harm the CDM are lower business-as-usual emissions growth in Annex B countries, higher supply of surplus emissions quota (hot air) from EIT countries, and also crediting under Article 3.4 of sequestration in agricultural soils, if the potential for these activities turns out to be large. If the United States participated in implementing the Kyoto Protocol, none of these factors would be a threat to a viable and sizeable CDM. The best strategy for the CDM is to prepare to be competitive in a low-demand, low-price market, and at the same time to strive for the United States to still come on board and implement the Kyoto Protocol.

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## Appendix 1: The PET model

PET (PET – Pelangi’s emissions trading model) is a relatively simple, easy-to-use model geared towards policy scenario analysis. The model provides a purely financial analysis of the emission reductions and carbon trade. Issues of economic relevance that the model can *not* shed light on include: impacts on commodity markets, for example, changes in oil prices and exports as a result of reduced global energy consumption; impacts on primary factor payments (such as land values); impacts on investment.<sup>13</sup> The PET model does not take account of positive or negative externalities associated with abatement activities, or of environmental or social impacts of emission reduction projects.

The model is static, providing a ‘snapshot’ representation of the global carbon market in the year 2010. In order to approximate the first full commitment period under the Kyoto Protocol (2008 - 2012), the volume data in the model can be multiplied by a factor of 5. Dynamic issues such as the accumulation of CDM credits over the years leading up to the first commitment period, changes in the price of emission credits through time, and banking of credits for future commitment periods are beyond the scope of the model in its present form.

The model finds the equilibrium distribution of abatement between countries, and the international trade flows – in other words, who produces, buys and sells how much of the commodity ‘carbon reduction’. Under unrestricted emissions trading, the equilibrium position is such that the marginal cost of abatement is equalized across all countries, and is equal to the price of carbon credits on the international market.<sup>14</sup> PET allows modelling of trade restrictions in the form of quantitative limits on emissions trading, limits on supply or limits on demand. The model also allows the modification of MACs, for example to account for the inclusion of sinks as an abatement option. PET contains an accounting module that keeps track of abatement and trade volumes, as well as the total cost of abatement, revenue from trade, and net economic costs/benefits.

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<sup>13</sup>Such flow-on economic effects can be analysed using general equilibrium models which capture sectoral interdependencies within economies as well as international commodity trade. For estimations of these impacts, see Polidano et al. (2000).

<sup>14</sup>See Ellerman and Decaux (1998) for a more comprehensive exposition of how MACs derived from GE models can be used for policy analysis in this way.

Estimates using MIT-EPPA parameters are available for all Annex B countries/regions, as well as for China, India and Brazil. In PET, MIT-EPPA data for the region ‘energy exporting countries’ is used as a proxy for the ‘middle East’ region. MACs for other non-Annex B countries and regions are calibrated using econometric analysis based on the share of coal in total emissions of any particular country. Regression analysis shows that the share of coal in emissions is a relatively reliable indicator, considering its simplicity. The purpose of choosing a simple indicator is to make it easy to estimate parameters for regions and countries not yet included in PET.

**Table A 1: MAC parameters**

Country group	a	b
<b>Annex B</b>		
United States	0.00672	1.57
European Union	0.03956	1.49
Japan	0.40761	1.68
Other Annex B	0.03434	1.59
Eastern Europe	0.05307	1.55
Former Soviet Union	0.04193	1.39
<b>Non-Annex B</b>		
China	0.00259	1.5
India	0.0226	1.5
Indonesia	2.46	1.5
Other Asia	0.0332	1.5
Brazil	6.71	1.5
Other Latin America	1.66	1.5
Middle East	0.217	1.5
Africa	0.0964	1.5

Note: Functional form of MAC curve:  $MC = a \cdot Q^b$ . Therefore, a lower value of a indicates higher abatement potential at a given marginal cost. The parameters refer to MC in \$/tC and Q (abatement quantity) in MtC. The parameters for Indonesia are calibrated based on a bottom-up estimation of abatement options (see State Ministry of Environment of the Republic of Indonesia, GTZ, World Bank 2001)

The MAC curves in PET for each country or region are calibrated to the emission reduction, in percentage of business-as-usual emissions, that is achieved at a given marginal cost. The functional form of MAC curves in PET is  $MC(q)=a \cdot Q^b$ , which

allows consistent constructions of MACs for regions/countries where no primary estimates are available. The exponential parameter  $b$  is taken from fitted curves in Ellerman and Wing (2000); it is relatively homogenous across groups of countries and can therefore be extrapolated to new countries. The parameter  $a$  can then be estimated on the basis of business-as-usual emissions and the estimated emissions reductions achieved at a given marginal cost.

Reduction of gas flaring is likely to provide relatively high volumes of emission offsets at low cost under the CDM, and has therefore been included in the modelling for this report.<sup>15</sup> As a result, the share of the CDM market estimated for important producers of oil and gas tends to be higher in PET than in other models, most of which do not explicitly include this abatement option.

The modelling of a limited number of no-regrets abatement options is another distinctive feature of PET calibration. While most economic modelling assumes that all abatement activities under the CDM have a positive cost (i.e., the CDM project reduces emissions, but its operation is more expensive than business-as-usual), the modelling here recognizes the fact that there is a potential for emission reduction projects that would be effectively costless or even profitable. Many of these projects would pass the test of investment additionality because of existing barriers to investment; for example credit constraints on plant operators, which prevent them from investing in cleaner and cheaper technologies. The underlying assumption is that a mechanism such as the CDM is necessary to 'make happen' projects that actually have no net cost, or are even profitable, principally by overcoming barriers to investment. In the standard scenario it is assumed that 1.5 percent of business-as-usual emissions in developing countries could be targeted by no-regrets CDM projects.<sup>16</sup> This assumption can be modified by the user. It is also assumed that all no-regrets options would become available at an international quota price equal to the transaction costs for emission credits or above.

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<sup>15</sup>Data on emissions from gas flaring from CDIAC (Carbon Dioxide Information Analysis Center, <http://cdiac.esd.ornl.gov>).

<sup>16</sup>This is lower than some estimates which put the potential for no-regrets measures in developing countries as high as 15-20 cent of business-as-usual emissions (IPCC 2001, p. 7). However, not all of the options may be eligible under the CDM.

## Appendix 2: Calculation of agricultural soil sinks

**Table A 2: Maximum annual agricultural sinks potential under different scenarios (million t CO<sub>2</sub>) and percentage of assigned amount (in brackets)**

Country	Cropland (million ha)	Grazing land (million ha)	CO <sub>2</sub> seq. Low scenario	CO <sub>2</sub> seq. Medium scenario	CO <sub>2</sub> seq. High scenario
<b>EU</b>	85.8	57.4	147.1 (3.8%)	336.3 (8.7%)	609.7 (15.8%)
<b>Australia</b>	48.2	405.5	17.7 (3.9%)	184.0 (41.0%)	499.1 (111.2%)
Bulgaria	4.5	1.6	5.8 (3.7%)	12.8 (8.2%)	22.3 (14.2%)
Croatia	1.6	1.6	3.5 (n.a.)	8.1 (n.a.)	14.9 (n.a.)
Czech Rep.	3.3	1.0	3.8 (2.2%)	8.4 (4.8%)	14.3 (8.2%)
Estonia	1.1	0.3	1.3 (3.5%)	2.8 (7.5%)	4.7 (12.6%)
Hungary	5.0	1.1	1.8 (1.4%)	4.2 (3.2%)	6.8 (5.1%)
Iceland	0.0	2.3	3.3 (129.4%)	8.3 (323.5%)	16.7 (647.1%)
<b>Japan</b>	4.9	0.4	4.2 (0.4%)	8.6 (0.7%)	13.7 (1.2%)
Latvia	0.2	0.6	1.0 (2.8%)	2.5 (7.0%)	4.9 (14.0%)
Liechten- stein	0.0	0.6	0.0	0.0	0.1
Lithuania	3.0	0.5	2.9 (6.1%)	6.2 (13.1%)	10.3 (21.7%)
<b>New Zealand</b>	3.3	13.3	21.9 (30.1%)	53.6 (73.7%)	104.7 (144.0%)
Norway	0.9	0.2	0.9 (1.6%)	1.8 (3.2%)	3.0 (5.0%)
Poland	14.4	4.0	16.5 (3.1%)	35.9 (6.8%)	61.3 (11.6%)
Romania	9.8	4.9	14.5 (6.0%)	32.5 (13.3%)	57.9 (23.8%)
<b>Russia</b>	126.8	90.0	93.0 (3.1%)	172.5 (5.7%)	308.2 (10.1%)
Slovakia	1.6	0.8	2.4	5.4	9.7

			(3.6%)	(8.1%)	(14.5%)
Slovenia	0.2	0.3	0.6 (3.1%)	1.4 (7.3%)	2.6 (13.5%)
Switzer- land	0.4	1.1	2.0 (4.0%)	4.8 (9.7%)	9.3 (18.8%)
<b>Ukraine</b>	33.6	7.8	36.1 (3.9%)	78.0 (8.5%)	131.4 (14.3%)
<b>USA</b>	179.0	239.3	273.9 (4.9%)	675.4 (12.1%)	1305.0 (23.4%)
<b><i>Sum Annex B</i></b>	<b><i>523.3</i></b>	<b><i>832.4</i></b>	<b><i>654.2</i></b> <b><i>(3.8%)</i></b>	<b><i>1643.6</i></b> <b><i>(9.5%)</i></b>	<b><i>3210.6</i></b> <b><i>(18.8%)</i></b>

The table uses the cropland/grassland sequestration rates per hectare listed in Sampson and Schole (2000, p. 199) for the whole cropland/grassland (data from FAO 2001) of the respective country. Obviously, only a small part is likely to be managed for carbon storage by the time of the commitment period. Still, the table shows that the amounts can be staggering. Even if only 10% of available agricultural land are managed, about 1% of total Annex B emissions would be covered under the medium variant. In the U.S., currently already 17.5% of cropland are managed in this way compared to just around 6% in 1990 (Anonymous 2001).