CONTENTS

1. Introduction 25
2. Analytical structure 26
3. Key structural characteristics of the Kyoto markets 26
4. GHG emissions projections from Annex B countries and potential demand for projectsto meet the Kyoto requirements 27
5. GHG emissions projections based on global modelling studies 28
6. Future development trends in GHG emissions from developing countries 29
7. GHG emissions projections for developing countries based on country study reports 29
8. Global IPCC emissions scenarios 30
9. General conclusions on CO_2 emissions from developing countries 32
10. General conclusions on global emission projections and potential "Kyoto" markets 33
11. Estimation of supply costs of CO_2 emissions reduction projects in developing countries 33
12. Conclusions on the potential for GHG emission reduction projects in developing countries 36
13. Conclusions on global markets for Kyoto CIMs 36
Notes 38
References 38
Appendix 1 40

CHAPTER II

Estimation of the global market potential for cooperative implementation mechanisms under the Kyoto Protocol

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1. Introduction

The Kyoto Protocol established by the Parties to the UNFCCC in December 1997 (UN 1992, Climate Secretariat 1998) includes a number of articles that provide a framework for cooperative GHG emission reduction activities between different Parties. The Protocol includes two project-based mechanisms: namely, Article 6 on Joint Implementation (JI) and Article 12 on the CDM that both aim at establishing markets for GHG emission reduction projects. JI projects can be carried out between Annex I countries of the UNFCCC, while CDM projects can be carried out as a cooperation between countries with a reduction commitment specified in the Kyoto Protocol (Annex B countries) and countries without such a commitment. Another "cooperative" mechanism of the Kyoto Protocol is Article 17 that facilitates emissions trading among Annex B countries.

The Kyoto Protocol specifies emissions reduction requirements to be met in the budget period 2008-2012, and it is possible to bank GHG emissions reductions achieved in the period 2000 through the CDM mechanism to be used in this budget period.[1]

京都

The paper estimates the potential demand and supply of GHG emission reduction projects through Annex B countries and the potential supply of such projects from non-Annex I countries, with emphasis mainly on the supply of CDM projects.

Sources of information for demand projections for GHG abatements

The demand projections for GHG emissions reduction projects are based on national communications submitted to the Climate Change Secretariat. Such communications do not exist for non-Annex I countries so supply projections for GHG emission reduction projects are constructed on the basis of current information provided by international studies for this region. These studies include recent scenario work that is going on as part of the IPCC Third Assessment, as well as information from coordinated international studies for developing countries, in particular, the ALGAS[2] studies which are a joint ADB, GEF and UNDP effort; and the UNEP Greenhouse Gas Limitation Costing Studies.

2. Analytical Structure

The paper considers a number of main issues related to future markets for GHG emission reduction activities related to the CIMs under the Kyoto Protocol.

A number of alternative scenarios for total GHG emissions and market size for GHG emission reduction activities are presented for the year 2010 (which is the midpoint of the Kyoto budget period) leading to a discussion on the range of GHG emissions reduction supply prices.

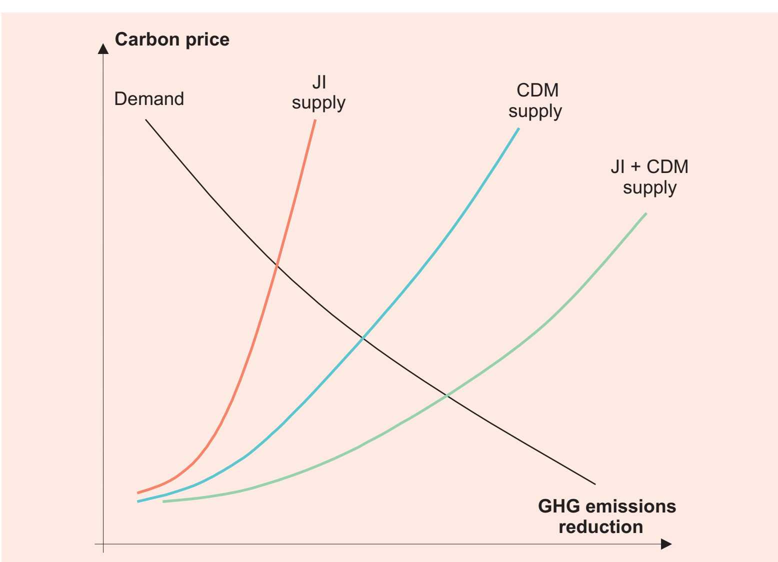
The basic idea is to establish an overview of the "Kyoto markets" like the highly stylized form provided in Figure 1. The Kyoto market structure is illustrated by a demand curve for GHG emissions reduction projects from Annex B countries, and three alternative supply curves for GHG emissions reduction projects representing reduction costs for JI projects, CDM projects and the combined supply of CDM and JI projects.

The GHG emission reduction supply curves in the JI and CDM markets are based on individual marginal GHG abatement cost curves which are horizontally summed to establish total supply curves for the markets. The supply curves are upward sloping to reflect the increase in marginal GHG emission reduction costs with increase in total abatement in the economy. The demand curve for a given Annex B economy as seen in the external market is the mirror image of its own supply curve and accordingly downward sloping; if the supply curve of domestic suppliers is integrated with the external supply curve, the demand curve of an Annex B country is a vertical line at the point of required GHG abatement in terms of its Kyoto Protocol target.

The demand for GHG emissions reduction projects in the Kyoto markets will then depend on three critical factors: namely, the total emissions reductions in Annex B countries required to meet the Kyoto targets, the marginal GHG abatement cost in the Annex B countries, and the supply price of GHG emissions reduction projects in non-Annex I countries and Annex B countries.

It should be emphasized that the demand and supply curves in the form presented in Figure 1 do not represent an actual estimation of relative GHG emission reduction costs or project supply in different segments of the Kyoto markets.

Figure 1: **Structure of the international markets for GHG emission reduction projects (not to scale)**



3. Key Structural Characteristics of the Kyoto Markets

The demand side of the Kyoto markets will, as earlier stated, depend on marginal GHG abatement costs and expected GHG emissions by Annex B countries, and thereby reductions required by these Parties to meet the Kyoto Protocol commitments. These commitments are defined in relation to1990/1995 base year GHG emissions in Annex B countries. A number of special issues relates to countries that are expected to have excess GHG emission permits[3] in the Kyoto budget period. This can for example be the case for a number of countries with economies in transition (EIT). It is not yet specified if such eventual excess emissions can be supplied as GHG emissions reduction projects to other Annex B countries or if they will be excluded from the Kyoto markets, and a number of alternative scenarios are therefore constructed to represent different rules in this area.

The supply side. The actual timing and operationalization of the future markets for GHG emissions reduction projects is very uncertain, and it is therefore difficult to assess the project supply. In particular, it is difficult to forecast the markets for CDM projects because available information about future emissions growth trends and marginal GHG emissions reduction costs in these countries are very limited and uncertain. Other major uncertainties relate to the actual extension of the CDM market to sectors and gases, where a number of specific issues remain to be clarified in relation to carbon sequestration projects and the land use sectors.

Accordingly, the current paper is limited to assessing GHG emissions projections and GHG emissions reduction studies for non-Annex I countries to the energy sector which is presently the best described sector in the international studies. This limited sectoral focus implies that CDM market supply projections presented in this paper should be considered only as representing a low estimate of potential market supply.

Market structure. The actual structure of the Kyoto markets will depend on various characteristics of the supply and demand side, such as the

- number of sectors and GHGs included in project supply;
- transparency and information across the markets;
- transactions costs;
- market power on the supply and demand side; and
- administration and verification costs.

Market power on the demand side may decrease the market price of carbon, while market power on the supply side may increase the price (see a more detailed discussion about markets in a paper by Ellerman and Decaux, 1998).

The actual market development may suffer from constraints in all the listed areas, and the assessment of market structure, trade and prices will therefore require a very detailed assessment of various institutional, financial, and legal aspects which is beyond the scope of the present paper.[4]

The analysis presented here, therefore, should only be seen as a preliminary attempt to consider potential market development trends given a few simple assumptions about the supply and demand of GHG emissions reduction projects.

4. GHG emissions projections from Annex B countries and potential demand for projects to meet the Kyoto requirements

This section will assess the future trends in GHG emissions from Annex B countries in order to estimate the magnitude of reduction activity required by the Kyoto Protocol. The assessment will be based on a review of Annex B countries national reports to the UNFCCC, and global modelling studies.

GHG emissions projections based on Annex B countries communications

The total projection of GHG emissions from the Annex B countries for the period 1990-2010 and reduction requirements (in 2010) to meet the Kyoto Protocol targets are presented in Table 1.[5] Total carbon emissions are projected to increase from 4939.5 mtC in 1990 to 5198.7 mtC in 2010 which corresponds to a 5 percent increase. This growth is unequally distributed among different regions and countries. European Union (EU) for example expects in total an emissions decrease from 1159.5 mtC in 1990 to 1095.9 mtC in 2010, while the USA for the same period expects an increase in GHG emissions amounting to as much as 19 percent. A number of EIT countries and the Former Soviet Union (FSU) expect a GHG emissions decrease in the period from 1990 to 2010. It should be noticed that the GHG emissions projection for the EU which is referred here is different from other internationally published projections in assessing relatively high base year GHG emissions in 1990 (Energy Journal, 1998). One consequence of these high 1990 GHG emissions is that the 2010 GHG emissions are projected to be lower than the 1990 level.

Annex B countries will experience uneven growth/ decrease in their GHG emissions

The GHG emissions reductions required to meet the Kyoto commitments vary considerably across countries. Table 1 shows that the "emission reduction burden" in 2010 measured as the GHG emissions reduction required as percentage of 2010 baseline emissions vary considerably across Annex B countries.

The EU countries together are projected to be committed to a total reduction of 40.6 mtC in 2010, if it is assumed that excess emissions are not used as offsets across countries, and 27.9 mtC if excess GHG emissions are traded internally in the EU. The reduction "burdens" are, in these cases, respectively 4 percent and 3 percent of the 2010 GHG emissions in the EU. It should be noted that these low reduction commitments rely on the high 1990 GHG emissions estimate for EU, which as earlier stated is different from the assumptions in other international studies.

京都

Table 1: **Emission projections for Annex B countries and reduction commitments as specified in the Kyoto Protocol based on national communications to the UNFCCC**

	1990 Emissions mtC	2010 Baseline Projection mtC	Emission Reduction Required to Meet Kyoto Protocol in 2010 mtC	Excess GHG Emissions in 2010 in Relation to Kyoto Protocol mtC
Austria	21.6	20.3	1.6	
Belgium	37.9	41.6	6.5	
Denmark	19.6	16.6	1.1	
Finland	19.8	18.5	-1.3	1.3
France	151.9	152.5	0.6	
Germany	329.5	266.9	6.6	
Greece	28.7	32.8	-3.1	3.1
Ireland	15.5	18.1	0.6	
Italy	145.2	129.6	-6.2	6.2
Luxembourg	3.7	1.8	-0.9	0.9
Netherlands	60.8	70.6	13.4	
Portugal	18.6	22.4	-1.2	1.2
Spain	82.1	98.6	4.2	
Sweden	18.1	20.4	1.6	
UK	206.5	185.1	4.4	
Sum EU	1,159.5	1,095.9		
Australia	113.3	144.1	21.7	
Canada	163.0	182.4	29.2	
Iceland	0.8	1.0	0.1	
New Zealand	19.8	22.9	3.1	
Norway	15.0	17.3	2.1	
Japan	337.2	388.2	71.2	
Switzerland	14.6	14.5	1.1	
USA	1,634.4	1,943.9	423.9	
Sum USA, non- EU and non-EIT	2,298.1	2,161.9		
Bulgaria	37.1	37.8	3.7	
Czech Republic	52.4	52.9	4.7	
Slovakia	19.9	18.2	-0.1	0.1
Hungary	27.8	28.2	2.1	
Poland	153.8	160.3	15.7	
Romania	72.2	55.6	-10.8	10.8
Slovakia	19.9	18.2	-0.1	0.1
Slovenia	5.2	5.3	0.5	
Sum EIT excl. former Soviet Union	368.4	345.2		
Estonia	11.1	5.5	-4.7	4.7
Latvia	9.7	5.5	-3.4	3.4
Lithuania	14.0	13.8	0.9	
Russia	828.4	793.9	-35	35.0
Ukraine	250.3	212.0	-38.3	38.3
Sum former Soviet Union	1,113.5	1,032.2		
Total demand if excess GHG emissions in Annex B countries are unused			620.6	
Total excess GHG emissions				105.1

The GHG emissions reduction "burden" will be relatively larger for a number of other countries that have projected relatively large GHG emissions increase from 1990 to 2010. These include Australia, that according to the estimates, will have to reduce its GHG emissions by 21.7 mtC which amounts to 15 percent, Canada with a reduction of 29.2 mtC corresponding to 16 percent, Japan with a reduction of 71.2 mtC corresponding to 18 percent, and finally the US with an estimated GHG emission reduction requirement of as much as 423.9 mtC corresponding to 22 percent increase from their baseline 2010 GHG emissions.

On this basis it can be concluded that the total GHG emissions reduction requirements in the EU seems to be relatively small in 2010, especially if the EU countries internally use excess GHG emissions in the region. This is in contrast to the reduction requirements in countries like Australia, Canada, Japan, and the US that potentially can be very large "customers" in the Kyoto markets.

Two alternative Kyoto market demand scenarios can be constructed on the basis of the numbers presented in Table 1, namely:

Scenario 1 which assumes that no excess GHG emissions are used to offset GHG emissions reduction requirements in Annex B countries. This will imply a total demand for the reduction amounting to 620.6 mtC.

Scenario 2 which assumes that all excess GHG emissions are used internally in Annex B countries to meet the reduction commitments required by the Kyoto Protocol. This will imply a total demand reduction amounting to 515.5 mtC (calculated as 620.6 mtC minus 105.1 mtC).

5. GHG Emissions Projections Based on Global Modelling Studies

A large number of global modelling studies have assessed the global demand and supply of GHG emissions reduction projects in order to assess the costs and benefits of different CIMs. In general, these models can be characterized as integrated assessment models, that in a rather aggregate way represent main regions of the world, such as Europe, FSU, Japan, US, other OECD countries, and a few large regions of developing countries. The value of the integrated assessment models is that they primarily provide a consistent global assessment of market structure, costs and benefits, and regional interactions, but they do not give detailed guidance on national GHG emissions reduction policies. There are also a number of limitations in the ability of these models to reflect special issues in the economies of countries with economies in transition and in developing countries (IPCC, 1996 Chapters 8 and 9). A comprehensive overview of the results of global integrated assessment models is given in the Energy Journal Special Issue entitled "*The Costs of the Kyoto Protocol*" (Energy Journal, 1999).

The GHG emissions projections for the year 2010 of the global modelling studies that are reported in the Energy Journal range, between 3,500 mtC and 5,000 mtC. These projections will imply that meeting the Kyoto targets will require a GHG emissions reduction in 2010 of approximately 30 percent to 35 percent of emissions in that year for the Japan, US, and other OECD countries, and approximately 15 percent to 25 percent for Western European countries (Energy Journal, 1998). A high estimate of the total demand for GHG emission reduction projects by Annex B countries in 2010 presented by Ellerman and Decaux (1998) is in total 1312 mtC.

6. Future Development Trends in GHG Emissions from Developing Countries

Developing countries (DCs) as Parties to the UNFCCC committed to submit national communications on GHG emissions, but these communications have not included projections of future development trends in GHG emissions. Therefore, there is no officially approved GHG emissions projections available for the DCs.

The GHG emissions projections for DCs in this paper are consequently based on the information provided by international country study programs conducted by ADB, UNDP/GEF, and UNEP, and on recent global IPCC emission scenarios (IPCC, 1999).

7. GHG Emissions Projections for Developing Countries Based on Country Study Reports

A large number of climate change country studies have recently been carried out for developing countries and these studies include rich information about likely future trends in GHG emissions. The projections of the individual country studies are not totally comparable because different methodological frameworks as well as modelling tools have been applied. A number of large coordinated international study programs such as the Asia Least-cost Greenhouse Gas Abatement Strategy (ALGAS) and the UNEP, however, have attempted to define a consistent methodological framework for the development of baseline GHG emissions projections and assessment of GHG emissions reduction potentials and costs. These programs can therefore be used for cross-country comparisons of key future development trends in GHG emissions. A number of conclusions from the ALGAS and UNEP are discussed in the following (ALGASa-m, 1999; UNEP/Risø 1999).

The ADB and UNEP studies exhibit a number of similarities in methodological approach. The studies are bottom-up sectoral assessments where various simulation and optimization models have been used. The GHG emissions projections included in the studies are related to national economic development plans using different approaches. Some studies make a direct link between macroeconomic forecasts and GHG emissions from the sectors, others use specific sectoral development plans which are typically available for the energy sector. The energy sectors have been most intensively studied in the country study programs, and a number of the key assumptions used in CO_2 emission projections for this sector in the country studies are shown in Table 2.

The ALGAS and UNEP studies cover a long term scenario period until 2020/2030, and the gross domestic product (GDP), primary energy consumption, and CO_2 emission growth rates shown in Table 2 therefore reflect longer time horizons than up to the first Kyoto commitment period. The country studies, however, can still be considered as a reasonable information source about future GHG emission trends for the next 10 to 15 years, because the studies, in reality, have primarily assessed short-term projections from National Development Plans covering a 5-10 years timeframe and has been the only available information. In this way longer time projections presented in the country studies will often, first and foremost, be an extension of short-term expectations.

The ALGAS and UNEP studies show a number of important similarities with regard to the assumptions about future development trends. All countries included in the programs experience annual GDP growth rate of more than 4 percent over the period and for Asian country studies more than 5 percent. Primary energy consumption is, in most of the studies, expected to grow more slowly than GDP as a consequence of technical efficiency improvements in the energy sectors. Bangladesh and Indonesia are exceptions in expecting higher growth in primary energy consumption than GDP, which is a reflection of the low present share of commercial energy sources in the supply systems in these countries.

In most developing countries studied, primary energy consumption will grow more slowly than GDP

CO_2 emissions are expected to grow faster than primary energy consumption or at the same rate for Argentina, PRC and India. The CO_2 intensity of the energy con-

Table 2: **Projected growth rates of GDP, primary energy consumption, and CO_2 emissions until 2020/30 based on UNEP and ALGAS country studies**

	GDP %	Primary Energy %	CO_2 Emissions %	Primary Energy/ GDP Elasticity	CO_2/Primary Energy Elasticity	CO_2/GDP Elasticity
UNEP studies						
Argentina	4.4	3.5	3.5	0.80	1.00	0.80
Ecuador	4.5	3.3	4.0	0.73	1.21	0.89
Botswana	4.6	2.8	3.3	0.61	1.18	0.72
Zambia	5.1	3.0	4.7	0.59	1.57	0.92
Indonesia	5.9	5.6	6.6	0.95	1.18	1.12
Viet Nam	7.7	6.8	8.4	0.88	1.24	1.09
ALGAS studies						
Bangladesh	6.9	7.3	7.0	1.06	0.96	1.01
PRC	8.2	3.7	3.7	0.45	1.00	0.45
India	5.8	5.0	5.0	0.86	1.00	0.86
Indonesia	6.8	7.3	8.0	1.07	1.10	1.18
Republic of Korea	4.2	3.9	4.6	0.93	1.18	1.10
Mongolia	7.9	7.5	7.6	0.95	1.01	0.96
Myanmar	6.4	2.6	5.5	0.41	2.12	0.86
Pakistan	5.7	4.8	6.5	0.84	1.35	1.14
Philippines	5.2	4.8	6.1	0.92	1.27	1.17
Thailand	6.3	4.2	5.0	0.67	1.19	0.79
Viet Nam	7.6	6.7	9.4	0.88	1.40	1.24

Note: Two countries, namely, Indonesia and Vietnam have participated in both country study programs but the results show a number of differences. The largest differences are seen in Indonesia where the UNEP and the ALGAS studies have used different models for the energy sector study.

Relatively large emitters of CO_2 among developing countries will experience lowest growth rates in CO_2 emissions

sumption in most cases is expected to increase over time because fossil fuels play a major role in future power production expansion. Hydropower is generally assessed to have a small future expansion potential due to capital constraints and environmental considerations. Establishment of nuclear facilities likewise is assessed to have a small potential, and has only been included in few of the country studies.

The general conclusions that can be drawn from the ALGAS and UNEP studies reported in Table 2 are that future CO_2 emissions from the countries considered will grow with annual rates of between 3 percent and 5 percent, with a number of Asian countries expecting growth rates as high as 7 percent (Bangladesh, Indonesia, Mongolia, and Viet Nam). The lowest expected CO_2 emission growth rates are seen in countries that are presently relatively large emitters (measured as absolute magnitude of CO_2 emissions), namely, Argentina, India, and in particular PRC.

These general country study results are in line with a review carried out as part of the IPCC Second Assessment Report (Halsnæs, 1996) based on 27 country studies for developing countries. These country studies included coordinated country study programs conducted by the Lawrence Berkely National Laboratory, US, and by UNEP, and a number of studies for PRC. This assessment concluded that the primary energy/GDP elasticity in the studies for 20-30 years timeframe is typically assumed to be around 0.7 to 0.8 and the corresponding CO_2/energy elasticity in most cases varies between 1.0 to 1.5 . The two elasticities taken together result in a total CO_2/GDP elasticity around 1.0 with a variation of +/- 0.2.

8. Global IPCC Emissions Scenarios

A number of global energy models include general projections of CO_2 emissions from different parts of the world including regions of developing countries. These models do not include detailed representations of specific characteristics of economic development trends or the energy sector in developing countries and cannot therefore be considered as providing accurate descriptions of energy sector development trends in the regions. The models, however, are helpful in the establishment of internally consistent CO_2 emission projections at the global scale.

IPCC has, as part of the ongoing Third Assessment, undertaken a review of scenarios produced by global models, have and clustered the scenarios into four scenario families, each based on a common specification of a number of main driving forces. These driving forces include assumptions on economic growth, population, technological change, energy supply structure, and a number of environmental and social policy priorities. A so-called "marker" scenario is selected to represent each of these four scenario families, and these "markers" are based on a specific model[6]. The marker scenarios are termed the A1-, the A2, the B1- and the B2 scenario (IPCC, 1999). The IPCC scenarios are constructed on the basis of a rich database of global energy models and economic models, and can therefore be considered as a good representation of the numerical range of global GHG emissions projections.

The IPCC scenarios include four regions, namely, OECD, REF, Asia and ALM. *OECD* includes the OECD countries, *REF* includes Central and Eastern Europe and new independent states of former USSR, *Asia* includes centrally planned Asia and PRC, South Asia, Other Pacific Asia, and the *ALM* region includes North Africa, Sub-Saharan Africa, Latin America and the Caribbean, and Middle East. The emissions projections in the IPCC report covers a scenario period up to 2100, but only the scenarios up to 2020 are considered here.

The CO_2 emission projections of the IPCC scenarios are shown in Table 3 and in Figures 2 through 5.

The IPCC scenarios include a range of total world CO_2 emissions from fossil fuels and industry of 9.7 btC to 8 btC in 2010. The trends in the emissions vary considerably across regions. OECD countries in general are expected to have a low rate of increase in emissions up to 2010 with annual growth rates below 1.0 percent in all scenario cases. The REF region is expected either to have continued emissions decreases like the trend from 1990 to 2000 or a small emissions increase from 2000 to 2010 across the scenarios.

The Asia and ALM regions with developing countries are expected to have relatively large future increases in CO_2 emissions from the present very low emissions levels today. CO_2 emissions from Asia are expected to increase from 1.8 btC to between 2.9 btC and 2.4 btC in 2010; this corresponds to annual growth rates in CO_2 emissions of between 2.9 percent and 4.9 percent from 2000 to 2010, which is a huge scenario case variation. The ALM region is projected to have an increase in CO_2 emissions from 1 btC in 2000 to between 1.3 btC and 2.3 btC in 2010. The corresponding annual growth rates across the scenarios vary between 2.6 percent and 8.7 percent annually for the period 2000-2010. On this basis it may be concluded that the CO_2 emission growth in the next decade until 2010 may occur primarily in the Asian and ALM regions. The projections for these regions, however, are very uncertain and has a very wide variation between high and low scenario cases.

Table 3: **IPCC scenarios CO_2 emissions from energy and industry in btC**

Region	1990	2000	2010	2020
World				
A1	6.0	6.9	9.7	12.1
A2	6.0	6.9	8.5	11.0
B1	6.0	6.9	8.4	9.9
B2	6.0	6.9	8.0	9.0
OECD				
A1	2.8	3.2	3.4	3.5
A2	2.8	3.2	3.5	4.0
B1	2.8	3.2	3.3	3.2
B2	2.8	3.2	3.5	3.7
REF				
A1	1.3	0.9	1.0	1.1
A2	1.3	0.9	1.0	1.2
B1	1.3	0.9	0.8	0.9
B2	1.3	0.9	0.8	0.8
Asia				
A1	1.2	1.8	2.9	4.1
A2	1.2	1.8	2.5	3.5
B1	1.2	1.8	2.5	3.1
B2	1.2	1.8	2.4	3.0
ALM				
A1	0.7	1.0	2.3	3.4
A2	0.7	1.0	1.5	2.3
B1	0.7	1.0	1.8	2.7
B2	0.7	1.0	1.3	1.5

Source: IPCC, 1999, Appendix VII table VII.

Figure 2: **IPCC CO_2 emissions projections for scenarios A1, A2, B1 and B2 for the period 1990-2020 for the OECD region (btC)**

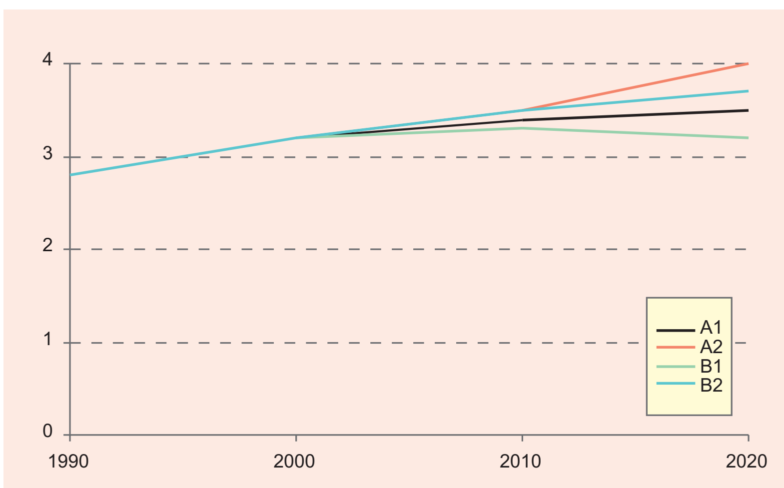


Figure 3: **IPCC CO_2 emission projections for scenarios A1, A2, B1 and B2 for the period 1990-2020 for Eastern Europe and the Former Soviet Union (btC)**

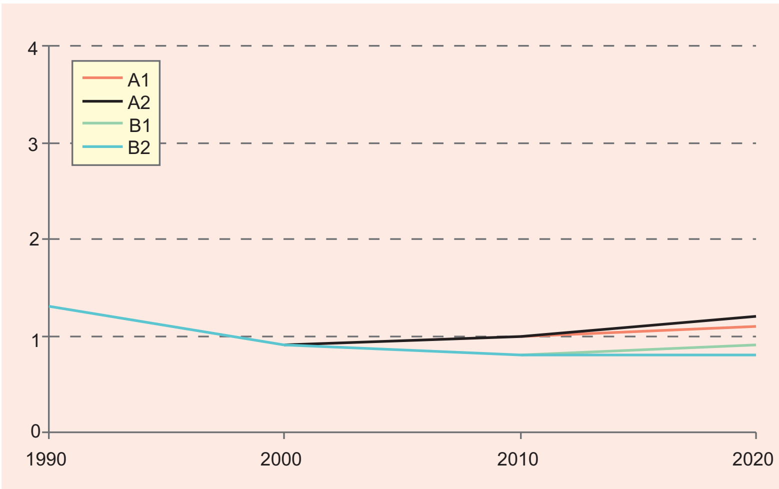


Figure 4: **IPCC CO_2 emission projections for scenarios A1, A2, B1 and B2 for the period 1990-2020 for Asia (btC)**

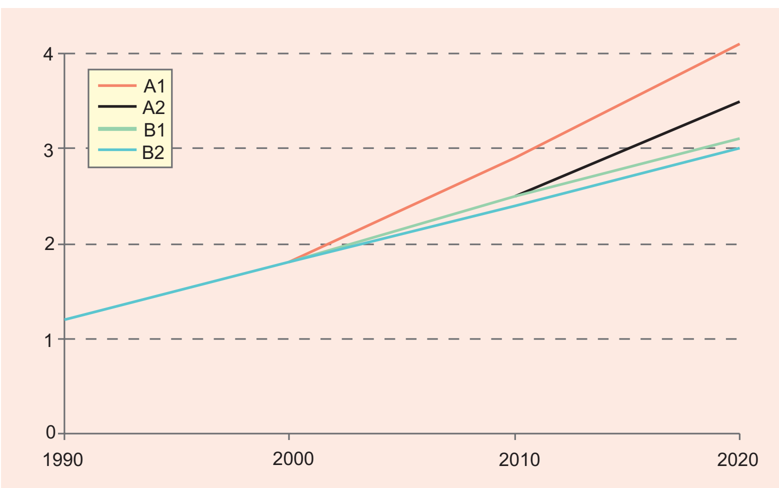
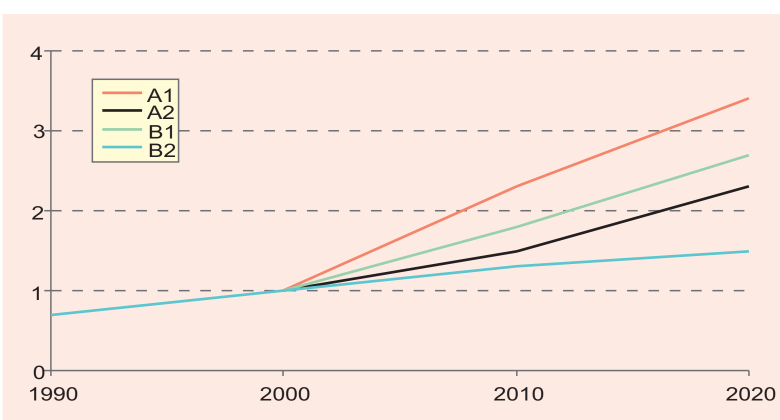


Figure 5: **IPCC CO_2 emission projections for scenarios A1, A2, B1 and B2 for the period 1990-2020 for North Africa, Saharan Africa, Latin America, and Middle East, (btC)**



The higher CO_2 emission growth rates that are expected for developing country regions imply that emissions from these regions will be increasingly important in the total global picture. The DC share of world CO_2 emissions is in the IPCC scenarios assessed to be 32 percent in 1990, and 41 percent in 2000. This share will increase to 54 percent in the A1 case and 46 percent in the B2 case in 2010, and to 45 percent in the A1 case and to 50 percent in the B2 case in 2020. The CO_2 emissions growth rates for the different regions assumed in the IPCC scenarios are shown in Table 4.

The previous section on GHG emissions projections for developing countries based on country studies reported a number of general conclusions on relationships between GDP growth, and growth in primary energy consumption and CO_2 emissions. It was concluded that most studies for developing countries expect a future primary energy and GDP elasticity below unity for a CO_2 and primary energy elasticity above unity. The growth rates of GDP and primary energy consumption of the IPCC marker scenarios are shown in Table 7 of Appendix 1. It can be seen that the OECD countries also expected to have a primary energy and GDP elasticity below unity and a CO_2 and primary energy elasticity above unity (see also Table 4). A general conclusion, accordingly, is that all regions of the world expect a delinking of economic growth and energy consumption, but this tendency seems to be offset by an increasing carbon intensity of energy consumption.

9. General Conclusions on CO_2 Emissions from Developing Countries

There is large uncertainty about future development trends in CO_2 emissions from developing countries and this is reflected both in the assumptions of various country studies, as well as in global models for developing country regions as reflected in the IPCC scenarios.

The UNEP and ALGAS studies concluded that CO_2 emissions will grow at an average annual rate of 3 percent-5 percent for most of the countries considered until 2020, with expected highest growth rates for Asian countries. The conclusions of the UNEP and ALGAS studies are in line with the results of other coordinated country study programs that have included more countries in Africa and Latin America as previously reviewed by IPCC, and currently available (IPCC 1996, Chapters 8 and 9; Halsnæs, 1996).

The IPCC scenarios assume a growth rate of between 3 percent to 7 percent for most of the scenario cases until 2010, decreasing to a range between 2.2 percent and 4.3

percent from 2010 to 2020. This relatively large expected decrease in CO_2 emissions growth rates from 2000-2010 to 2010-2020 cannot be directly supported by the UNEP and ALGAS studies.

The short-term expectations of emissions growth until 2010 are more similar across studies and in the rest of the paper. It will be assumed that the scenario range from the IPCC scenarios for 2000 to 2010 represents a reasonable assumption for developing countries.

10. General Conclusions on Global Emissions Projections and Potential "Kyoto" Markets

The national communications from Annex I countries and the recent IPCC scenarios for developing countries may then be integrated in a total summary of market potentials as provided in Table 5.

The total demand for GHG emissions reduction from Annex B countries to meet the Kyoto commitments will, in the low estimate reported in Table 5, amount to 620.6 mtC in 2010 in demand scenario 1 and 515.5 mtC in demand scenario 2, in terms of the assumptions reported in Table 1. The estimates foresee excess GHG emissions to be available in EU, Eastern Europe and the FSU: respectively 12.7 mtC, 11.0 mtC and 81.4 mtC.

These estimates of GHG emission reduction requirements in 2010 to meet the Kyoto Protocol by Annex B countries must be considered low. Other studies, as for example the study by Ellerman and Decaux, have estimated higher reduction requirements. The range of GHG emissions reduction requirements may also be assessed on the basis of the IPCC scenarios reported in Table 3. Despite the fact that IPCC scenarios only include CO_2 emissions from the energy sector and industry, a rough calculation of reduction requirements may be made on the basis of the 1990 and 2010 data. Assuming that 2010 CO_2 emissions from the Annex B countries should be 5 percent below the 1990 level, the IPCC scenarios suggest a range of required GHG emissions reductions between 500 mtC and 1,300 mtC. An overview of the different GHG emissions reduction estimates for 2010 are given in Table 6.

Developing countries are estimated to have in total between 5,200 mtC and 4,000 mtC CO_2 emissions in 2010 from fossil fuel use and industry. The total CO_2 emissions from developing countries in this way are very large compared with the magnitude of the Kyoto reduction commitments. Developing countries, furthermore, in addition to potential CO_2 emission reduction related to fossil fuels and industry, may have a potential for carbon sequestration projects in forestry, and for GHG emissions reduction projects in agriculture.

Table 4: **Annual growth rates in CO_2 emissions from fossil fuels and industry assumed in the IPCC scenarios (percent)**

Region	1990–2000	2000–2010	2010–2020
World			
A1	1.4	3.5	1.9
A2	1.4	2.1	2.6
B1	1.4	2.0	1.7
B2	1.4	1.5	1.2
OECD			
A1	1.3	0.6	0.4
A2	1.3	0.9	1.7
B1	1.3	0.4	-0.4
B2	1.3	0.9	0.6
REF			
A1	-2.7	1.1	1.0
A2	-2.7	1.1	1.8
B1	-2.7	-1.1	1.2
B2	-2.7	-1.1	0
Asia			
A1	4.1	4.9	3.5
A2	4.1	3.3	3.4
B1	4.1	3.3	2.2
B2	4.1	2.9	2.2
ALM			
A1	3.6	8.7	4.0
A2	3.6	4.2	4.3
B1	3.6	6.0	4.2
B2	3.6	2.6	1.4

Regions: OECD, REF: Central and Eastern Europe and new independent states of former USSR. Asia: Centrally planned Asia and the PRC, South Asia, Other Pacific Asia. ALM: Middle East and North Africa, Latin America and the Caribbean, Sub-Saharan Africa.

11. Estimation of Supply Costs of CO_2 Emissions Reduction Projects in Developing Countries

This section reviews international studies on GHG emissions reduction costs for developing countries in order to establish generic information about supply curves for carbon reduction projects in these countries. The main sources of information are the ALGAS and the UNEP coordinated country study programs. This section presents emissions reduction cost curves for GHG emissions reduction projects in a number of countries, in addition to several general conclusions about reduction cost ranges and reduction potential. A discussion of the main categories of low cost GHG emissions reduction options that

Table 5: **Total GHG emissions in 1990 and 2010, and reduction commitments according to the Kyoto Protocol based on national communications (low estimate)**

	Total GHG Emissions in 90 mtC	Total Emissions in 2010 mtC	Kyoto Reduction Commitment mtC	Excess Emmissions[8] mtC
EU	1,159.5	1,095.9	40.6	12.7
Australia	113.3	144.1	21.7	
Canada	153.0	182.4	29.2	
Iceland	0.8	1.0	0.1	
Japan	337.2	388.2	71.2	
New Zealand	19.8	22.9	3.1	
Norway	15.0	17.3	2.1	
Switzerland	14.6	14.5	1.1	
United States	1,634.4	1,943.9	423.9	
Eastern Europe	368.4	358.3	26.7	11.0
Former Soviet Union	1,113.5	1,032.2	0.9	81.4
Demand Scenario 1 for GHG emission reduction in Annex B countries			620.6	
Demand Scenario 2 for GHG emission reduction in Annex B countries			515.5	
DC's (only CO_2 from fossil and industry)				
A1 case	1,900	5,200		
A2 case	1,900	4,000		
B1 case	1,900	4,300		
B2 case	1,900	4,500		

Note: A higher estimate on the total demand for GHG emission reduction in Annex B countries based on Ellerman and Decaux foresee as earlier referred a total demand amounting to 1.312 mtC in 2010.

have been identified in the country studies are also presented.

The UNEP and ALGAS studies made, as already stated, an assessment of the costs of GHG emissions reduction options in the energy, forestry, agriculture and waste management sectors. These reduction costs may be illustrated in cost curves, where the marginal costs of emissions reductions are depicted in merit order for increasing emissions reduction targets.

Emission reduction targets may be defined in various ways in cost curves. The GHG emissions reductions can be either measured as reductions in relation to base year emissions (e.g., 1990), or in relation to future baseline emissions. The latter approach has been used in the cost curves presented. The time dimension of the GHG emissions reductions may also be considered in different ways in cost curves. Some countries report in their cost curves the total accumulated reduction potential over the scenario period of the study[7] and others report the emission reduction potential as the average annual reduction over a given timeframe of the projects considered[9]. Most of the ALGAS studies use the first of these approaches, while the UNEP studies predominantly use the latter approach.

The ALGAS and UNEP study cost curves presented in this section are based on an assessment of GHG emissions reduction options that are assumed to be implemented over a 10-20 year time horizon. This timeframe is longer than the period up to first Kyoto protocol budget period, and some of the options represented in the national cost curves might therefore have an implementation period that goes beyond 2010.

Cross-country comparisons of GHG limitation costs exhibit a number of difficulties originating from differences in country approaches and assumptions. In particular, differences in baseline scenario approaches have major implications on study results. Some countries define their baseline scenario as a projection of current trends in energy system development, where part of current inefficiencies in the systems will persist in the future. This creates a potential for low cost GHG limitation policies that in some cases, may have a benefit in the form of fuel or electricity savings. Other countries define their baseline case as an efficient development of energy systems, implying that GHG limitation policies will imply additional costs compared with the baseline case.[10] As argued previously, the establishment of the baseline scenario for long-term studies in developing countries is characterized by significant uncertainties and the studies have therefore not been based on a uniformly standardized baseline scenario approach. These differences in approaches suggest that cross-country comparisons should focus on broad assessments of GHG limitation costs for the main categories of options; and on the comparison of these costs when the reduction targets get stricter, rather than on an accurate cost assessment of a large number of policy options.

Figures 5 and 6 show emissions reduction cost curves that have been established on the basis of a number of individual country study reports from the ALGAS and UNEP studies.[11]

The ALGAS cost curves depicted in Figure 6 show a total accumulated CO_2 emission reduction potential of between 10 percent and 25 percent of total emissions in the period 2000 to 2020. The marginal reduction cost is below \$25 per ton of CO_2 for a major part of this potential; and a large part of the potentials in many of the country studies associated with very low costs are, in some cases, assessed to be negative. The magnitude of the potential for low cost options in the individual country cost curves depends on the number of options included in the studies. Countries like Myanmar and Pakistan have included relatively many options and assessed a relatively large potential for low cost emission reductions.

The individual cost curves are constructed on the basis of detailed technical and economic information about the individual projects assessed by the national teams, and a detailed reporting of these may be found in the country reports (ALGASa-m, 1999). Several of the studies considered technical options in end use energy efficiency improvements, electricity saving options in the residential and service sectors, and introduction of more efficient motors and boilers. The studies included relatively few GHG emissions reduction options related to conventional power supply. An overview of the main categories of options used to construct the cost curves is given in Appendix I, Table 8.

The UNEP cost curves shown in Figure 7 exhibit a number of interesting similarities across countries. All country cost curves have a large potential for low cost emission reductions in 2030, where 25 percent (and in some cases up to 30 percent) of the emissions reduction can be achieved at a cost below \$25 per ton of CO_2. The magnitude of this "low cost potential" is, like in the ALGAS studies, influenced by the number of climate change mitigation options. The actual options considered in the individual studies are reported in Appendix I, Table 9, where it can be seen that some of the countries like Ecuador and Botswana experience a very steep increase in GHG emissions reduction costs when the reduction target approaches 25 percent.

It must be noted that these country studies have primarily assessed end use energy efficiency options and a few renewable options, and have not included major reduction options related to power supply which could probably have extended the low cost emissions reduction area. The studies for Hungary and Viet Nam estimate a relatively small emissions reduction potential, which primarily can be explained by the specific focus in the studies on end use efficiency improvements and electricity savings that do not include all potential reduction areas in the countries.

The only country that has included major reduction options related to power production in the UNEP study is Estonia, through which the inclusion of nuclear power, lim-

Table 6: **Range of GHG emissions reduction estimates**

	2010 Baseline GHG mtC	2010 Baseline Emissions from Energy mtC	Reduction Requirement in 2010 mtC
National communication low estimate	5,205		516
National communication high estimate	5,205		621
Model estimate	4,956		1.312
IPCC A1		4,400	500
IPCC A2		4,500	1,300
IPCC B1		4,100	600
IPCC B2		4,300	400

Figure 6: **Emissions reduction cost curves based on ALGAS studies**

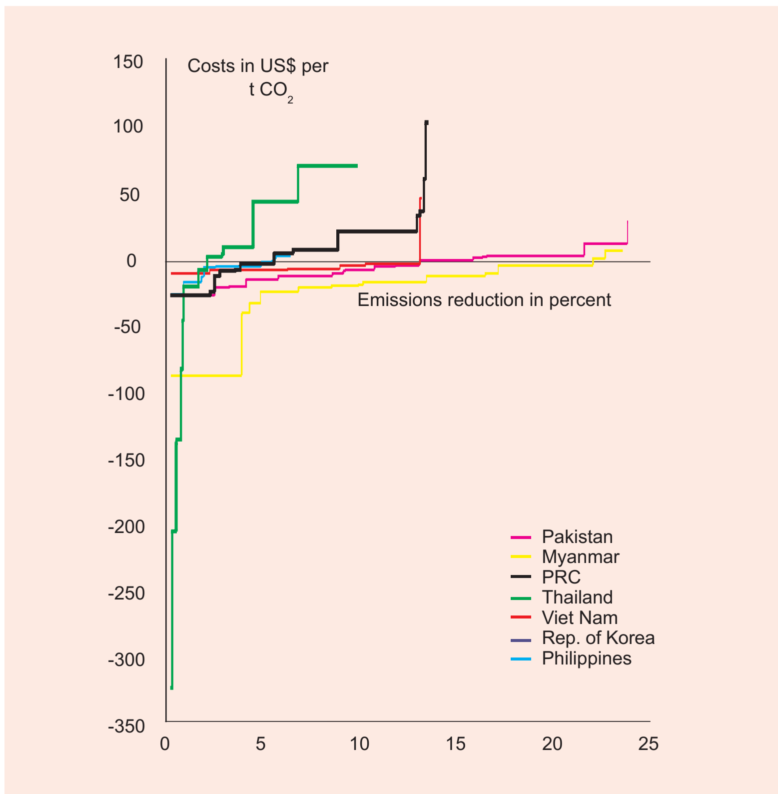
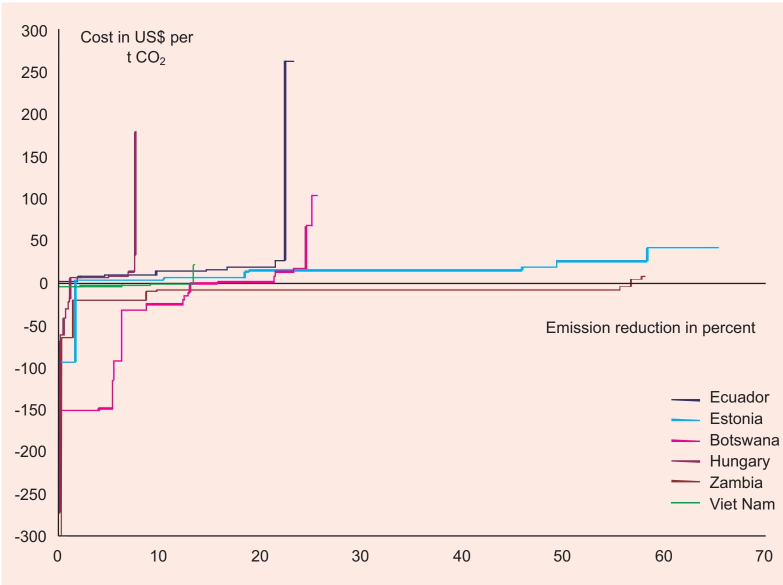


Figure 7: **Cost curves based on UNEP studies**



Estimated potential for GHG reductions depends crucially on the options evaluated

ited electricity exports, and wind turbines, has estimated a reduction potential as large as 65 percent reduction of the expected CO_2 emissions in 2030 at a cost below $42 per ton of CO_2. The many technical options included in the country study for Estonia explain the relatively large lost cost potential identified in this study.

The options in the low cost part of the UNEP cost curves typically include energy efficiency improvements in household and industry, and a number of efficiency or fuel switching options for the transportation sector. The household options include electricity savings such as compact fluorescent lamps (CFLs) and efficient electric appliances and, for Zambia, improved cooking stoves. The main categories of GHG reduction options depicted in the cost curves are shown in Table 9. A large number of end use efficiency options have been assessed for electricity savings, transport efficiency improvements, and household cooking devices, but very few large scale power production facilities.

There are a number of similarities in the low cost GHG emission reduction options identified in the ALGAS and UNEP studies. Almost all studies have assessed efficient industrial boilers and motors to be attractive climate change mitigation options and this conclusion is in line with the conclusions of earlier UNEP studies (UNEP, 1994). A number of transportation options, in particular, vehicle maintenance programs and other efficiency improvement options, are also included in the low cost options. Most of the studies have included a number of renewable energy technologies such as wind turbines, solar hot water systems, photovoltaics, and bioelectricity. The more advanced of these technologies tend to have medium to high costs in relation to the above mentioned low-cost options. A detailed overview of the country study results is given in the individual country study reports (UNEP, 1999a-h, ALGASa-m, 1999).

12. Conclusions on the Potential for GHG Emissions Reduction Projects in Developing Countries

It was previously concluded that the total CO_2 emissions from fossil fuels and industry in developing countries according to recent IPCC scenario work will range from 5,200 mtC to 4,000 mtC in 2010. A number of conclusions have also been drawn on the marginal costs of GHG emissions reduction projects in developing countries, based on coordinated study efforts in the ALGAS and UNEP studies. For both these studies it has been concluded that GHG emissions reductions in the energy sector of the order of magnitude of 10 percent to 15 percent of future baseline emissions can be achieved at a cost below $25 per ton of CO_2 (corresponding to a cost below about $91 per ton of carbon). These study results are in line with previous conclusions of reviews of country studies for developing countries, and the conclusions from the ALGAS and UNEP studies therefore can be used to draw some generic conclusions.

If the costing results of the ALGAS and UNEP studies are applied to the total future GHG emissions in developing countries, it implies that the potential for low cost GHG emissions reduction projects in developing countries will be between 400 mtC and 520 mtC in 2010 potentially, if it is assumed that 10 percent of the GHG emissions will be supplied to a global market in 2010.[12]

13. Conclusions on Global Markets for Kyoto CIMs

The paper has estimated the total demand for GHG emissions reduction projects from Annex B countries and has concluded that the total demand for such projects including domestic actions in Annex B countries, JI projects, emissions trading, and CDM, in total are projected to be between 600 mtC and 1,300 mtC in 2010.

Part of the global demand for GHG emissions reduction projects can probably be covered by “excess” GHG emissions in Eastern Europe and the FSU, which will decrease the demand for CDM projects as well as domestic actions.

The demand for CDM projects supplied by developing countries will most likely not be very large compared with the total future GHG emissions in these countries assessed for the developing countries as a total region. Even in the most extreme case, where CDM projects are assumed to cover a large part of the Annex B countries reduction commitments in 2010, these projects will be relatively small compared with total future CO_2 emissions from fossil fuels and industry according to the IPCC scenarios for developing countries.

A large portfolio of end use energy efficiency projects have been identified to supply low cost GHG emissions reduction options from developing countries. These projects include improved cooking stoves, efficient lighting, air conditioning systems, refrigerators, industrial boilers and motors, vehicle tune-up programs, improvement of public transportation systems, energy efficient industrial processes, reduced power transmission losses, various power production technologies, renewable energy technologies, and various other options. Country study programs conducted by ADB and UNEP include detailed assessment of the GHG emissions reduction potential and related costs for a large number of developing countries which establish a good basis for further development of CDM project assessments.

The global market for GHG emissions reduction projects can potentially be dominated by a few number of actors on the demand as well as on the supply side. This is the case on the demand side because a very large share of the total GHG emission reduction is going to be undertaken by the Australia, Canada, Japan, and US. On the supply side, a few number of countries including Brazil, India, and PRC, presently as well as in the future, will contribute large parts of the GHG emissions from developing countries. Market power on the demand side can potentially lead to lower prices of GHG emissions reduction projects, while market power on the supply side can result in higher prices than the prices established on a fully competitive market. The actual development of market structure depend on various issues including operationalization of the Kyoto mechanisms, trade coalitions, and bargaining power.[13]

The global market for GHG abatements is susceptible to both demand and supply side cartelization

Notes

1 The GHG emissions in the budget period are measured as the average annual emissions over the period.

2 ALGAS is an acronym for the Asia Least-cost Greenhouse Gas Abatement Strategy

3 The terminology "excess GHG emission permits" is meant to reflect a case where national GHG emission constraints specified by the Kyoto Protocol is expected to be larger than the likely GHG emissions of the country in the 2008-2012 budget period. This is sometimes referred to as "hot air."

4 Editor's note: On these aspects, see the papers by Banuri and Gupta, and Ghosh, in this volume.

5 Based on national communications to the UNFCCC and a paper by Zhang (1999).

6 The marker scenarios are constructed with the following models: A1: The AIM model (Asian Pacific Integrated Model from the National Institute of Environmental Studies in Japan), A2: the ASF model (Atmospheric Stabilization Framework Model from ICF Consulting USA), B1: the IMAGE model (Integrated Model to Assess the Greenhouse Effect from RIVM the Netherlands) , B2: the MESSAGE model (Model for Energy Supply Strategy Alternatives and their General Environmental Impact from IIASA in Austria).

7 Excess emissions are the sum of national GHG emissions in 2010 will be below the Kyoto targets for 2010.

8 Total accumulated emissions measured in relation to ALGAS cost curve

9 Cost curves containing a number of target reductions in one year can in this approach be regarded as snapshot pictures of the costs of achieving a given reduction that year.

10 Examples of different baseline case approaches in the UNEP country studies, can, be seen in the studies for Ecuador and Botswana. Ecuador has defined its baseline case for the energy system to include all technical options that would be economically efficient when GHG limitation is not a policy objective. The GHG limitation policy identified for Ecuador as a consequence does not include any options with negative costs. Botswana, on the other hand, has assumed that some efficiency losses are present in the baseline case energy system, which implies a potential for reduction options with negative costs.

11 Some of the country study reports do not report the information in a format that can be easily transformed into cost curves formatted as in Figure 5 and Figure 6 and they are therefore not included in the figure. These countries are in the UNEP studies for Argentina, Mauritius and Senegal, and in the ALGAS studies for Bangladesh, India, Indonesia and Mongolia.

In addition to studies for developing countries, the UNEP studies included two studies for countries with economies in transition, namely, Estonia and Hungary. The results of these two studies are included in the tables and cost curve figures showing the differences in their case from developing country studies.

12 These estimates of GHG abatement cost and supply of GHG abatements from developing countries (by means of the CDM) would suggest an annual potential value of -C trades through the CDM of \$36.4 billion to \$47.3 billion if the market for -C is competitive. Other authors, working with varying assumptions have estimated the value of CERs traded at \$5 billion to \$21 billion annually. Vrolijk (1999) takes a "best estimate" of \$10 billion annually. Of course, realization of any of these estimates of the potential for CERs trades depends on a number of factors.

References

ALGAS (1999a). Asian Least-cost Greenhouse Gas Abatement Strategy. Summary Report. Asian Development Bank. Manila, Philippines.

ALGAS (1999b). Asian Least-cost Greenhouse Gas Abatement Strategy. Profiles of Investment and Technical Assistance. Greenhouse Gas Abatement Projects. Asian Development Bank. Manila, Philippines.

ALGAS (1999c). Asian Least-cost Greenhouse Gas Abatement Strategy. Bangladesh. Asian Development Bank. Manila, Philippines.

ALGAS (1999d). Asian Least-cost Greenhouse Gas Abatement Strategy. People's Republic of China. Asian Development Bank. Manila, Philippines.

ALGAS (1999e). Asian Least-cost Greenhouse Gas Abatement Strategy. India. Asian Development Bank. Manila, Philippines.

ALGAS (1999f). Asian Least-cost Greenhouse Gas Abatement Strategy. Indonesia. Asian Development Bank. Manila, Philippines.

ALGAS (1999g). Asian Least-cost Greenhouse Gas Abatement Strategy. Republic of Korea. Asian Development Bank. Manila, Philippines.

ALGAS (1999h). Asian Least-cost Greenhouse Gas Abatement Strategy. Mongolia. Asian Development Bank.

Manila, Philippines.

ALGAS (1999i). Asian Least-cost Greenhouse Gas Abatement Strategy. Myanmar. Asian Development Bank. Manila, Philippines.

ALGAS (1999j). Asian Least-cost Greenhouse Gas Abatement Strategy. Pakistan Report. Asian Development Bank. Manila, Philippines.

ALGAS (1999k). Asian Least-cost Greenhouse Gas Abatement Strategy. Philippines. Asian Development Bank. Manila, Philippines.

ALGAS (1999l). Asian Least-cost Greenhouse Gas Abatement Strategy. Thailand. Asian Development Bank. Manila, Philippines.

ALGAS (1999m). Asian Least-cost Greenhouse Gas Abatement Strategy. Viet Nam. Asian Development Bank. Manila, Philippines.

Climate Secretariat (1998). The Kyoto Protocol.

Ellerman, A.D. and Decaux, A. (1998). Analysis of Post-Kyoto CO_2 Emission Trading Using Marginal Abatement Cost Curves, MIT USA (photo copy).

Energy Journal (1999). The Costs of the Kyoto Protocol: A Multi-Model Evaluation. Special Issue.

IPCC (1999). Special Report on Emission Scenarios, Second order draft. IPCC Working Group III.

IPCC (1996). Climate Change 1995. Economic and Social Dimensions of Climate Change. Scientific-Technical Analysis. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Halsnæs. K (1996). The economic of climate change mitigation in developing countries. Energy Policy Special Issue Vol. 24, No 10/11.

Halsnæs, K, Callaway, J. M. and Meyer, H. Methodological Guidelines. Risø National Laboratory, UNEP Collaborating Centre on Energy and Environment, 1998) (Economics of Greenhouse Gas Limitations, Main Report) 212 p.

UN (1992). United Nations Framework Convention on Climate Change. International Legal Materials, Vol. 31, 1992, p. 849-73.

UNEP (1994). UNEP Greenhouse Gas Abatement Costing Studies. Part One: Main Report, UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999a). Economics of Greenhouse Gas Limitations. Country Study Series Argentina. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999b). Economics of Greenhouse Gas Limitations. Country Study Series Ecuador. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999c). Economics of Greenhouse Gas Limitations. Country Study Series Botswana. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999d). Economics of Greenhouse Gas Limitations. Country Study Series Zambia. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999e). Economics of Greenhouse Gas Limitations. Country Study Series Vietnam. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999f). Economics of Greenhouse Gas Limitations. Country Study Series Indonesia. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999g). Economics of Greenhouse Gas Limitations. Country Study Series Hungary. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

UNEP (1999h). Economics of Greenhouse Gas Limitations. Country Study Series Estonia. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

Vrolijk, C (1999). The Potential Size of the Clean Development Mechanism. Second International Conference on Emerging Markets for Emissions Trading, 26-27 April 1999, London.

Zhang, ZhongXiang (1999). Estimating the Potential Market for all Three Flexibility Mechanisms under the Kyoto Protocol, draft paper.

Appendix 1

Table 7: **Annual growth rates in GDP and primary energy consumption assumed in the IPCC scenarios**

	GDP Growth 1990-2000	GDP Growth 2000-2010	GDP Growth 2010-2020	Primary Energy Growth 1990-2000	Primary Energy Growth 2010-2020	Primary Energy Growth 2010-2020
OECD						
A1	2.3	2.1	2.1	1.3	0.9	0.8
A2	2.0	1.8	1.5	1.3	1.0	1.2
B1	2.1	2.5	2.3	1.7	0.9	0.2
B2	2.6	2.3	1.3	1.2	1.1	0.9
REF						
A1	-3.1	6.5	6.8	-3.3	1.0	1.4
A2	-1.2	2.3	3.4	-3.9	1.4	2.2
B1	-2.7	3.5	5.3	-5.8	-0.7	0.9
B2	-0.9	1.8	4.1	-1.2	-0.8	0.7
Asia						
A1	6.1	7.9	7.8	2.4	3.7	3.6
A2	5.1	4.3	4.2	4.4	3.7	3.9
B1	6.9	5.9	6.1	3.7	3.0	2.5
B2	8.8	7.5	6.2	3.5	3.1	2.8
ALM						
A1	3.6	7.0	6.9	4.1	5.6	4.6
A2	3.6	4.1	4.3	4.0	4.2	4.9
B1	3.8	6.0	5.4	3.8	5.8	3.6
B2	3.6	3.2	4.0	2.5	2.5	2.1

Regions: OECD, REF: Central and Eastern Europe and new independent states of former USSR. Asia: Centrally planned Asia and China, South Asia, Other Pacific Asia. ALM: Middle East and North Africa, Latin America and the Caribbean, Sub-Saharan Africa.
Source: IPCC, 1999, Appendix VII table VII.

Table 8: **Main categories of energy sector GHG emission reduction options identified in the ALGAS studies**

	CO_2 Equivalent Potential (mill. t CO_2)	Cost per Tonne of CO_2 Equivalent (US$)
Thailand (total accumulated CO_2 reductions)		
Lighting in the residential sector	2.00	-323.1
Lighting in the commercial sector	22.70	-204.5
Fuel efficiency improvements in transport	4.80	-139.0
Cooling systems in the commercial sector	19.70	-136.4
Industrial boilers	10.90	-83.3
Refrigerators in the residential sector	4.10	-46.1
Efficient motors in industry	77.60	-20.6
Cogeneration in industry	47.10	-8.3
Coal to natural.gas power production	77.80	1.8
Air-conditioning in the residential sector	8.50	3.6
Coal to natural gas in power production	155.40	9.1
Gas to nuclear power production	233.10	43.4
More nuclear power than previous options	310.90	69.6
Viet Nam (total accumulated CO_2 reductions)		
Efficient air conditioners	49.90	-10.5
Efficient refrigerators	84.50	-8.5
CFL's	15.30	-8.3
Efficient electrical motors	67.20	-.2
Wind power	32.90	-4.6
Efficient cooking	70.10	-4.2
Fuel switching	1.60	46.4
Republic of Korea (annual CO_2 reduction potential)		
Efficient heating in the commercial sector	0.14	-33.8
Efficient heating in the residential sector	7.31	-7.7
Efficient air conditioning in the commercial sector	0.52	-6.4
Efficient motors in industry	24.19	-4.9
Efficient lighting in the commercial and residential sectors	14.28	-2.4
New power generation technologies	2.87	1.2
Efficiency improvements in transportation	3.42	22.8
Efficient boilers in industry	0.02	31.6
Fuel substitution in the power sector	4.55	44.8
Philippines (annual CO_2 reduction potential)		
CFL's	1.10	-26.3
Industrial boilers	0.37	-26.0
System loss reduction	2.32	-17.2
Industrial motors	0.24	-13.7
Efficient air conditioning.	1.47	-6.1
Efficient refrigerators	0.37	-5.4
Heat rate improvement	5.26	-5.1
Efficient transport	1.34	-2.9
Wind power	0.24	-1.6
Biomass	0.12	0.3
Solar	0.12	1.4

Continued next page

Table 8 Cont'd

	CO_2 Equivalent Potential (mill. t CO_2)	Cost per Tonne of CO_2 Equivalent (US$)
Myanmar		
Biomass cookstoves	6.92	-87.8
Kerosene lamps	0.08	-42.0
CFLs in the commercial sector	0.75	-41.2
CFLs in the residential sector	1.05	-33.8
Cogeneration in industry	3.72	-24.4
Motors in industry	3.28	-21.4
Industrial boilers	2.61	-20.0
Air-conditioning in the commercial sector	0.51	-18.9
Vehicle maintenance programmes	2.03	-17.6
LPG cooking systems	4.16	-17.2
Transmission & Distribution losses	5.75	-13.2
Mass transit systems	1.29	-11.1
Combined cycle	9.32	-4.2
Cogeneration in the commercial sector	1.22	0.5
Bio electricity	1.73	5.8
Pakistan		
Cogeneration	105.80	-27.6
Efficient lighting	36.80	-21.9
Efficient fans	42.00	-20.7
Efficient tube wells	77.50	-15.2
Transmission & Distribution losses	128.40	-13.2
Industrial motors	5.30	-12.5
Industrial boilers	25.70	-10.5
Waste fuels	2.20	-10.3
Water heaters	2.50	-9.2
Efficient transistors	72.80	-7.8
Engine maintenance	51.60	-5.3
Solar water heaters	4.40	-5.0
Waste heat recycling	53.70	-4.2
Mini-micro hydro power	1.00	-2.1
Gas T&D	130.80	-1.4
Vehicle maintenance	23.40	0.7
Wind power	1.50	1.3
Building design	9.80	1.9
Natural gas to substitute oil and coal	238.30	2.4
Engine design	106.60	11.6
PV electricity	0.60	28.3
People's Republic of China (annual emission reduction in relation to 2010 emissions)		
Technical renovation of motors for general use	97.56	-27.5
Cutting ratio of iron/steel & iron industry	9.36	-24.4
Renovation of kilns for wet cement prod.	12.96	-13.1
Energy saving lighting	38.88	-8.9
Synthetic ammonia process	11.16	-7.8
Industrial boilers	75.60	-3.9
Continues casting of steel making	7.56	-3.9
Efficiency improvement in conventional power plant	47.16	4.4
Nuclear power	110.52	6.9
Hydro power	195.48	20.3
IGCC power production	7.92	32.5
Biogas and other biomass	9.00	35.8
Wind power	4.68	60.0
Solar thermal	5.40	101.7

Table 9: **Main categories of GHG reduction options in UNEP studies**

	CO_2 Equivalent Potential (1000 tonne)	Cost per Tonne of CO_2 Equivalent (US$)
Ecuador		
Efficient lighting	1,090	2
Wind turbines and geothermal electricity	260	7
Hydroelectricity	1,330	9
Efficient electric appliances	3,070	9
Efficient industrial motors	2,930	14
Natural gas-fired power plants	570	16
Efficient lighting and refrigerators	640	16
Efficient electric appliances (urban households)	2,250	19
Efficient industrial boilers	550	19
Efficiency improvements in air transport	620	27
Efficient gasoline vehicles	550	263
Total CO_2 emissions in 2030		
58.8 mill tons		
Viet Nam (accumulated emissions 1994-2030)		
Efficient air conditioners	158,000	-4.4
Efficient refrigerators	266,000	-3.6
CFL's	50,000	-3.4
Efficient electric motors	212,000	-3.0
Wind turbines	104,000	-1.9
Efficient coal stoves	212,000	-1.8
Fuel switching in power plants	14.000	21.2
Total accumulated energy sector emissions 1994 to 2030		
7520 mill. tons CO_2		
Botswana		
Road freight to rail	460	-152
Efficient lighting	170	-150
Tillage	10	-115
Pipeline	90	-93.0
Prepayment meters	290	-34
Geyser timeswitches	430	-25
Solar home systems	10	-21
Power factor correction	50	-14
Efficient boilers	20	-11
Fuel pricing	20	0
Biogas from landfills	310	0
Vehicle inspection and efficient motors	640	1
Solar geysers	20	8
PV electricity	210	13
Biogas rural households	140	17
PV waterpumps	700	67
Refforestation	700	103
Diesel to electric rail	600	539
Total CO_2 equivalent emissions in 2030		
11.7 million tons		

Table 9 Cont'd

	CO_2 Equivalent Potential (1000 tonne)	Cost per Tonne of CO_2 Equivalent (US$)
Zambia		
Vehicle maintenance	30	-909
Ethanol blend	120	-97
Improved stoves	760	-29
Diesel boilers	50	-12
Coal briquettes	60	-12
Electric stoves	4,810	-11
Fuel oil boilers	110	-4
Cement production	110	9
Coal fired boilers	40	15
Total CO_2 emissions from the energy sector in 2030		
10.5 million tons		
Estonia		
Energy conservation buildings	284	-94
Electricity imports	1,450	4
Oil-shale plants	1,317	6
Energy conservation roofs	71	14
Nuclear power	4,461	15
Biomass cogeneration	552	19
Limited elec. Export	1,491	25
Wind turbines	1,165	42
Total baseline CO_2 emissions in 2025		
16.5 million tons		
Hungary		
CFL lighting	100	-273
Hot water metering	94	-69
Efficient faucets and showerheads	311	-62
Public lighting	163	-41
Ventilation	299	-30
Efficient faucets and showerheads (public)	72	-22
Thermostats	145	-19
Building insulation	3,586	6
Energy forest	1,976	8
Insulated windows	565	13
Combustion maintenance	64	33
Active solar DHW	91	180
Total baseline CO_2 emissions in 2030		
97.3 million tons		