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Carbon credit supply potential beyond 2012

A bottom-up assessment of mitigation options

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Abstract

In the context of climate change mitigation commitments and post-2012 negotiations questions have arisen around the potential and dynamics of the carbon market beyond 2012. This study focuses on gaining insight in the supply side of carbon credits after 2012 by studying potential and costs of greenhouse gas reduction options in the Clean Development Mechanism (CDM) and other flexible mechanisms. An elaborate analysis of future demand for credits is outside the scope of this report. It is concluded that the potential for greenhouse gas reduction options in non-Annex I countries in 2020 is likely to be large. This study has also made clear that the extent to which this potential can be harnessed by the CDM strongly depends on future eligibility decisions, notably for avoided deforestation, the application of the additionality criterion, and to a lesser extent the success of programmatic CDM and the adoption rate of technologies. Compared to this market potential, demand for carbon credits could be in the same order of magnitude, depending on the post-2012 negotiations and domestic reductions in countries with commitments. In addition to CDM, Joint Implementation projects in Russia and Ukraine and banked and new Assigned Amount Units may play a significant role in post-2012 carbon markets.

Executive summary

Climate change is an increasingly important issue on national and international policy agendas. Recently announced mitigation commitments include a 20 to 30% greenhouse gas emissions reduction in 2020 compared to 1990 for the European Union, and a unilateral target of 30% greenhouse gas reduction in 2020 compared to 1990 for the Netherlands. Both may consider utilising the flexibility provided by the international carbon market. In this context, questions have arisen around the potential and dynamics of the carbon market beyond 2012. It is difficult to study the demand for carbon credits, however, as it depends on political decisions that will not be taken until the coming years. This study therefore focuses on gaining insight in the supply side of carbon credits after 2012 by studying potential and costs of greenhouse gas reduction options in the Clean Development Mechanism (CDM) and other flexible mechanisms.

The main conclusion of this report is that the potential supply of carbon credits is large compared to the likely demand up to 2020. The technical potential for greenhouse gas reduction options up to 20 €/tCO_2-eq abated in non-Annex I countries is likely to be larger than 4 GtCO_2-eq/yr in 2020. If avoided deforestation is excluded this potential is approximately 3 Gt/yr. This study has also made clear that the extent to which this potential can be harnessed by the CDM strongly depends on future eligibility decisions, notably for avoided deforestation, the application of the additionality criterion, and to a lesser extent the success of programmatic CDM and the adoption rate of technologies. Taking these uncertainties into account we estimate the market potential for CDM projects at 1.6 - 3.2 GtCO_2-eq/yr at costs up to 20 €/tCO_2-eq in 2020. Demand for carbon credits could be in the same order of magnitude, depending on the post-2012 negotiations and domestic reductions in countries with commitments. In addition to CDM, Joint Implementation (JI) projects in Russia and Ukraine and banked and new Assigned Amount Units (AAUs) may play a significant role in post-2012 carbon markets.

The results have been obtained by addressing the following questions:
- What is the potential supply of credits from CDM projects from 2013 to 2020?
- How many credits will the current CDM project pipeline supply?
- How may programmatic CDM and other modifications impact the supply of credits?
- What is the role of JI, AAUs and voluntary emission reductions in the carbon market beyond 2012?

In dealing with these research questions we have made use of recently completed work that developed Marginal Abatement Cost (MAC) curves for mitigation technologies in non-Annex I countries, Russia and the Ukraine. We updated these MAC curves using information from recent studies, and added CO_2 capture and storage and forestry to the technology database. The revised MACs were reviewed by experts from various regions with particular expertise on GHG reduction technologies. In order to reflect the uncertainties relating to CDM projects and to perform a sensitivity analysis, an assessment of recent and possible future developments in the CDM was done, and the impact of different scenarios of future decisions and CDM practices on the MAC was calculated. Finally, a set of qualitative post-2012 demand and supply scenarios was developed to gain insight in the interplay between the different types of carbon credits. In addition to the questions above, we discussed recent developments with regard to procurement mechanisms.

The CDM, as of October 2007, includes more than 800 registered projects, which could generate approximately 120 million Certified Emission Reductions (CERs, equal to 120 MtCO_2-eq/yr reduction) per year on average in 2013 - 2020. If projects in the validation stage and expected upcoming projects up to 2012 are included, the CER supply could be 450 million per year. The relative importance of industrial gas projects in the CER supply, notably N_2O and

HFCs-related projects, is expected to decrease, and energy efficiency and renewables projects are expected to increase, both in relative and absolute terms.

The technical and economic potential for CDM, however, is much larger, as shown in Figure ES 1. This MAC curve is based on an inventory of the potential and cost of GHG emission reduction technologies for more than 30 non-Annex I countries, as well as regional abatement cost studies for other greenhouse gases. The cost in € is calculated to the price index of 2006, using a 1.2 $/€ exchange rate. For CO_2 capture and storage (CCS), afforestation/reforestation and avoided deforestation no bottom-up studies were found, and therefore new cost and potential assessments were carried out. For CCS a potential of approximately 158 $MtCO_2$/yr in 2020 was found, based on technology adoption scenarios for power plants and industrial early opportunities, but excluding natural gas processing due to lack of data.

The potential for afforestation and reforestation is based on the potential for increasing current rates of creating forest plantations, and is estimated to be 74-235 $MtCO_2$/yr in 2020. For avoided deforestation (AD) we assumed that current rates of deforestation will continue, resulting in an estimated technical potential of 2.3 $GtCO_2$/yr in 2020. Although all numbers in the MAC curve are surrounded by uncertainties, they are particularly large for avoided deforestation. The estimate should therefore be regarded in a different context than the potential for the other options, as its size and uncertainties would otherwise obscure the overall results.

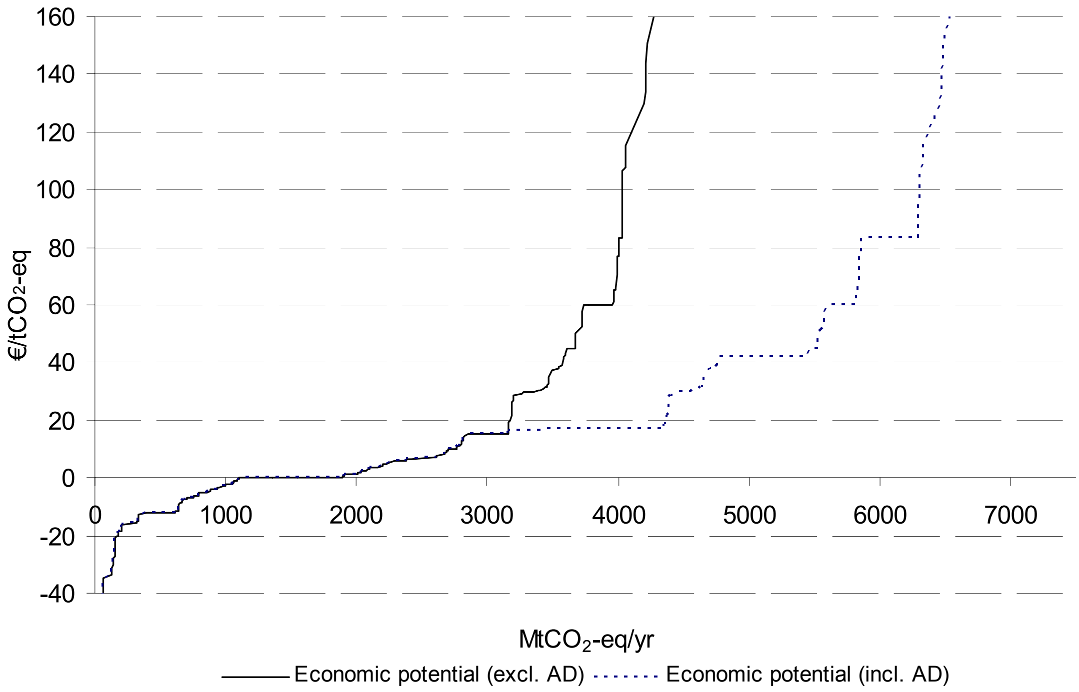

Figure ES 1 *MAC non-Annex I region in 2020, with and without avoided deforestation (AD)*

Of the two MAC curves shown in Figure ES 1, the one excluding avoided deforestation should be regarded as the most representative. In this case the economic abatement potential below 20 €/tCO_2-eq is 3.2 $GtCO_2$-eq/yr, with a potential at zero or negative net cost of 1.7 Gt/yr. Energy efficiency and methane reduction options constitute the largest share of this no-regret potential.

The estimates in Figure ES 1 should be regarded as the technical potential and associated cost for mitigation options. To what extent this potential can be realised by the CDM depends on a number of other (non-economic) factors: 1) the eligibility of technologies under the CDM; 2) the future application of the additionality criterion; 3) the success of programmatic CDM; and 4) the existence of non-financial barriers related to the uptake of technology. We have estimated the impact of these factors on the technical potential of CDM projects. To examine the impact on the potential, we developed four scenarios along two axes, whereby the first three factors are represented in the horizontal axis ('conducive environment') and the non-financial barriers in the vertical axis ('technology optimism'), as shown in Figure ES 2.

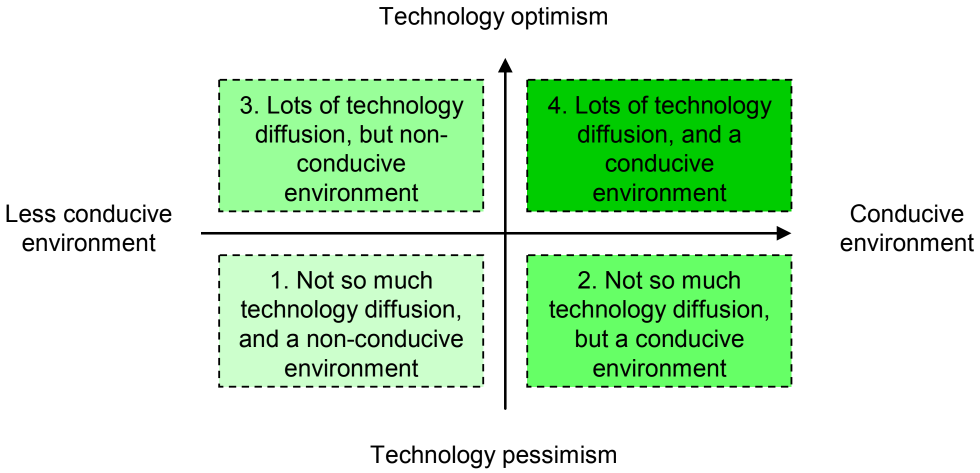

Figure ES 2 *Scenarios relating to the CDM market potential*

The scenarios are applied to the non-Annex I MAC curve (excluding avoided deforestation) by downsizing the potential for each technology according to the factors in the scenario. In Scenario 1, for instance, CCS is not eligible and the potential is therefore multiplied by 0. Figure ES.3 shows the results of the scenarios for the market potential.

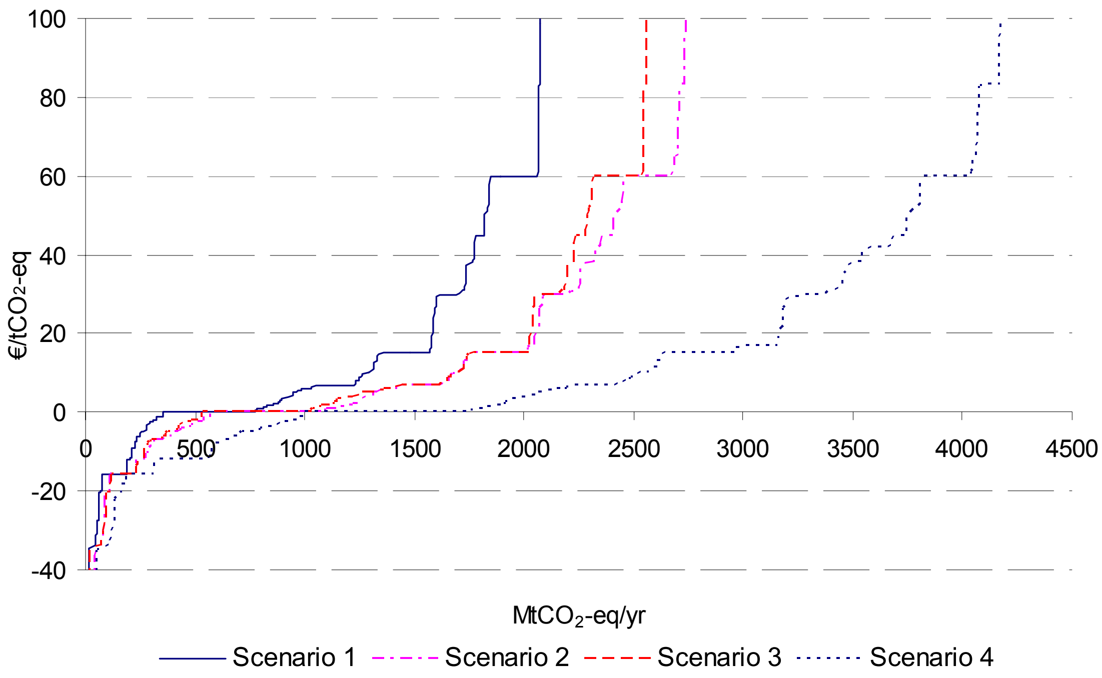

Figure ES 3 *CDM market potential (excluding avoided deforestation) according to four scenarios*

It can be observed that the abovementioned uncertainties may have a significant impact on the market potential for CDM projects, which is estimated at 1.6 and 3.2 $GtCO_2$-eq/yr up to 20 €/tCO_2-eq in 2020 for the most pessimistic and optimistic scenario respectively. The difference can be explained by the impact of non-financial barriers on energy efficiency (which represent 1.6 Gt or 25% of the technical potential), and its related rules on additionality in the barrier analysis. Strictness in the application of the additionality criterion is expected to impact renewable energy, cement blending, avoided deforestation and waste fuel utilisation projects.

Transaction costs are taken into account in the MACs by calculating premiums that are added to the abatement cost, which are relate to 1) the CDM project cycle, and 2) investment risk in different non-Annex I countries. In addition to the transaction costs there could be non-economic barriers that cannot readily be expressed in the transaction cost. Therefore the scenarios were developed, and these should be regarded as an attempt to give a semi-quantitative illustration of what the impact of several uncertainties on the abatement potential for CDM projects may be. It is not an exhaustive study into the market potential.

A number of limitations to this study should be mentioned:
- In our bottom-up approach not all abatement options in all countries are covered.
- Uncertainties regarding CCS and particularly avoided deforestation are large.
- The abatement cost of most mitigation options is highly sensitive to energy prices, which have not been harmonised across the options, which adds uncertainty to projections for the future.
- The assumptions in the scenarios regarding additionality and technology adoption are to some extent (inherently) subjective.

We have made conservative assumptions with regard to the major uncertainties, and therefore consider the results a conservative estimate. This is confirmed by a rough comparison with results from other recent studies, which show GHG abatement potential in non-Annex I countries on the order of 5 to 7 $GtCO_2$-eq per year in 2020. Our bottom-up MAC data however have been affirmed by expert reviewers in China, India, Brazil and Senegal.

Programmatic CDM may help to remove some of the barriers to CDM, and could therefore play a significant role in mobilising the potential for energy efficiency projects, particularly in the buildings and transport sector. However, it is difficult to make a quantitative distinction between the potential for single-project CDM and programmatic CDM. The main reason for this is possible overlap between project-based and programmatic-based CDM potential, indicating that a separate estimate of the *additional* potential by programmatic CDM cannot be given. However, it can be said that programmatic CDM will increase the likelihood of implementation of those abatement technologies particularly affected by streamlining the project-based procedures. These options could amount to between 1 and 1.6 $GtCO_2$-eq/yr below 20 €/tCO_2-eq in 2020. Sectoral crediting mechanisms are likely to be conducive to mobilising a significant part of the GHG reduction potential (i.e. more than 1 $GtCO_2$-eq/yr) in high-emitting industry sectors, however several political and implementation barriers exist to establish such mechanisms. This includes difficulty in establishing a common metric to measure sector performance without creating excess allowances and the negotiation of fair targets.

In addition to CDM, JI projects in Russia and Ukraine may be a source of carbon credits beyond 2012. The greenhouse gas abatement potential up to 20 €/tCO_2-eq is estimated to be in the range of 0 to approximately 400 Mt/yr in 2020, primarily in methane reduction projects. The post-2012 potential depends on a number of factors, notably climate mitigation commitments and upcoming national emission reduction policies.

A qualitative assessment of possible developments regarding post-2012 climate negotiations shows that the shape, scope and size of the carbon market is highly uncertain. Demand for credits depends on the new commitments Annex I (and possibly also some non-Annex I) countries are willing to take on, and whether the full regime will remain based on a cap-and-trade principle. Two post-2012 climate scenarios were examined: A) continuation of the current situation with no progress on expanding the list of countries in Annex B (20% reduction target for the EU), and B) a rapid roll-out of targets to a list including the world's two biggest emitters, US and China, in addition to 30% reduction for the EU. Compared to emissions in 2005, the EU-27 needs further reductions of 0.5 to 1.0 $GtCO_2$-eq/yr in 2020 to achieve the target of 20 to 30% emissions below 1990 levels and may consider using carbon credits to assist in achieving this target. Demand for GHG reduction by the US in Scenario B could be even higher than that. This qualitative assessment, therefore, yields that the demand for carbon credits may be in the same range as the CDM market potential of 1.6 to 3.2 $GtCO_2$-eq/yr in 2020. Banked AAUs from the 1st Kyoto commitment period (up to 5 $GtCO_2$-eq) and excess AAUs for China in Scenario B, however, could also cover a significant part of demand for carbon credits between 2013 and 2020.

The level of integration of different carbon markets remains uncertain. It is possible that the carbon market will remain fragmented into different types of credits, including EUAs, CERs, and AAUs. It is also possible that most of the market corresponds to a single (albeit 'risk-adjusted') price for one tonne of CO_2-eq, thus being fully integrated. Linking between regional markets can differ in nature, from direct links where credits are fully fungible across more than one system to indirect links, where for example separate systems all draw on a single pool of project-based credits. It is even conceivable (but not considered likely) that voluntary credits gain an official status, which will result in competition between VERs and CERs for several technologies.

Contents

Abbreviations

AAU	Assigned Amount Unit (emission allowances to Member to the KP)
ACM	Approved Consolidated Methodology
ALGAS	Asia Least-cost Greenhouse gas Abatement Studies
AM	Approved Methodology
AMS	Approved Small-scale Methodology
Annex I countries	Countries included in Annex I to the Kyoto Protocol
AR	Afforestation & Reforestation
BAU	Business As Usual
BRT	Bus Rapid Transit
C	Carbon
CCS	CO_2 capture and storage
CDM EB	CDM Executive Board
CDM	Clean Development Mechanism
CER	Certified Emission Reduction (carbon credit under the CDM)
CH_4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
COP/MOP	Conference of the Parties serving as the Meeting of the Parties to the KP
CPA	CDM Programme Activity
CSIA	Climate Stewardship and Innovation Act
DC	Developing Country
DSM	Demand side management
ECCP	European Climate Change Programme
ECN	Energy research Centre of the Netherlands
EE	Energy Efficiency
EEA	European Environmental Agency
ENCOFOR	ENvironment and COmmunity based framework for designing afFORestation
ENEF	Energy efficiency
ERPA	Emission Reduction Purchase Agreement
ERU	Emission Reduction Unit (carbon credit under JI)
ETS	Emission Trading Scheme
EU	European Union
FAO	Food and Agricultural Organisation
FRA	Forest Resource Assessment
GCP	Global Carbon Price model
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Green Investment Scheme
$GtCO_2$-eq	Gigatonnes (billion tonnes) of CO_2 equivalents
GWh	GigaWatthour (= 10^9 Wh)
HCFC-22	Hydrocarbonfluorocarbon 22
HFC-23	Hydrofluorocarbon 23
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
KP	Kyoto Protocol
LFG	Landfill gas
LUC	Land-use change

LULUCF	Land-use, land-use change and forestry
MAC	Marginal Abatement Cost
MCER	Million CERs
Mha	Million hectares
$MtCO_2$-eq	Megatonnes (million tones) of CO_2 equivalents
MWh	MegaWatthour
N_2O	Nitrous oxide
NEIA	National Ecological Investment Agency (Ukraine)
NM	New Methodology
ODA	Official Development Assistance
OECD	Organisation for Economic Cooperation and Development
pCDM	Programmatic CDM (= PoA)
PCF	Prototype Carbon Fund
PDD	Project Design Document
PFC	Perfluorocarbon
PoA	Programme of Activities (under the CDM)
PV	Photovoltaics
RGGI	Regional Greenhouse Gas Initiative
SCM	Sectoral Crediting Mechanism
SD-PAM	Sustainable Development Policies and Measures
SF6	Sulphurhexafluoride
SSC	Small-scale CDM
TEAP	Technology and Economic Assessment Panel
TETRIS	Technology Transfer and Investment Risk in International emission trading
TWh	TeraWatthour (=10^{12} Wh)
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VER	Voluntary Emission Reductions
WEO	World Energy Outlook
ZEW	Zentrum für Europäische Wirtschafsforschung

1. Introduction

In the context of more ambitious targets for greenhouse gas (GHG) reduction, both on the European Union level and in the Netherlands, it is important to study the likely developments of the Clean Development Mechanism (CDM) market after the Kyoto Protocol ends in 2012. The Netherlands have domestically committed to a greenhouse gas emission reduction of 30% in 2020 relative to 1990 levels and may consider continuing a degree of carbon trading to meet the target, although the aim is to achieve the required reductions domestically. The EU has committed to a 20 to 30% reduction of GHG emissions in 2020 compared to 1990, depending on commitments by other countries. Emissions (including LULUCF) in 1990 and 2005 for the EU27 were 5.3 and 4.7 $GtCO_2$-eq respectively (EEA, 2007), and the targets of 20 and 30% would therefore correspond to 4.2 and 3.7 $GtCO_2$-eq in 2020 respectively.

Currently, the international carbon market outside the EU Emission Trading Scheme is dominated by the CDM. During recent years, the CDM market has boomed, procedures have matured, and the mechanism has gained considerable support from host countries, Annex I countries, business and even civil society. There seems to be general consensus that the CDM should be continued in one form or another under a new commitment.

In addition to the CDM, the Kyoto Protocol recognises two additional flexible mechanisms for carbon trading: International Emissions Trading (IET) and Joint Implementation (JI). These mechanisms are also prominent in the first Kyoto commitment period, but their role in the years after 2012 is very uncertain and strongly depends on the negotiations in the UNFCCC on post-2012 commitments. Voluntary emissions reductions could also play a role, depending on the development of the market in the coming years. If the negotiations result in a protocol similar to the Kyoto Protocol, CDM is likely to remain the dominant trading mechanism, with additions from JI and international emissions trading. If the negotiations result in less defined rules for commitments, the voluntary market may play a larger role (generating Voluntary Emission Reductions - VERs). However, the VER market would have to use the same overall GHG mitigation potential as CDM in non-Annex I countries and JI in Annex I countries. So although the practical rules and procedures for approval of the credits would differ depending on the outcome of post-2012 negotiations, the GHG mitigation potential is a technical given and can be assessed nevertheless.

After carbon trading was first introduced, much has happened on the policy and technology front. Afforestation and reforestation is now a real category of CDM projects with its own set of rules to guarantee permanence of greenhouse gas emission reductions, while the eligibility of reduced emissions from avoided deforestation is under discussion. The emerging technology of CCS is not yet approved for use under the CDM, but might be a promising way of decarbonising electricity supply in coal-dependent countries, and reducing emissions in the oil and gas sectors in others. The CDM potentials of these technologies are not yet known in detail, and should be considered for a complete picture of the expanding post-2012 CDM market.

The CDM, however, has also been subject to criticism. This is particularly due to the windfall profits related to HFC-23 projects, the sustainable development criteria that are determined by the host countries, and the elaborate procedures that are designed to maintain environmental integrity but end up favouring large-scale projects in economically relatively prosperous countries rather than small-scale projects with extensive development benefits. In addition, CDM might have the perverse effect that host countries do not embark on e.g. renewable energy policies or regulations anymore as that could render their renewable energy CDM projects not additional. Several mechanisms have been proposed and initiated to solve some of these issues. Programmatic CDM is the most concrete at the moment, but more elaborate variants such as sectoral CDM may arise in the future. Developments of further voluntary credit schemes may also have interaction with CDM in the period post-2012.

This report aims to shed light on the potential for carbon credit after 2012 by incorporating the above mentioned developments and uncertainties into GHG abatement studies that are already available. More specifically, the research questions are:

- What is the potential supply of credits from CDM projects between 2012 and 2020?
- What is the supply of the current CDM project pipeline?
- How may programmatic CDM and other modifications impact the supply of credits?
- What could be the role of JI, AAUs and voluntary emission reductions in the carbon market beyond 2012?

The main focus is on the potential credit supply of the CDM, which is carried out in two steps: 1) assessment of the technical and economic potential for emission reduction in developing countries and 2) analysing barriers for CDM projects in order to make an estimate of the likely CDM market potential. In this report two types of scenarios are introduced: a) those related to uncertainties regarding the CDM market (for step 2) above) and b) quantitative and qualitative post-2012 climate regime scenarios in relation to the global carbon market, which aim to better grasp the interplay between CDM, JI, IET and VERs.

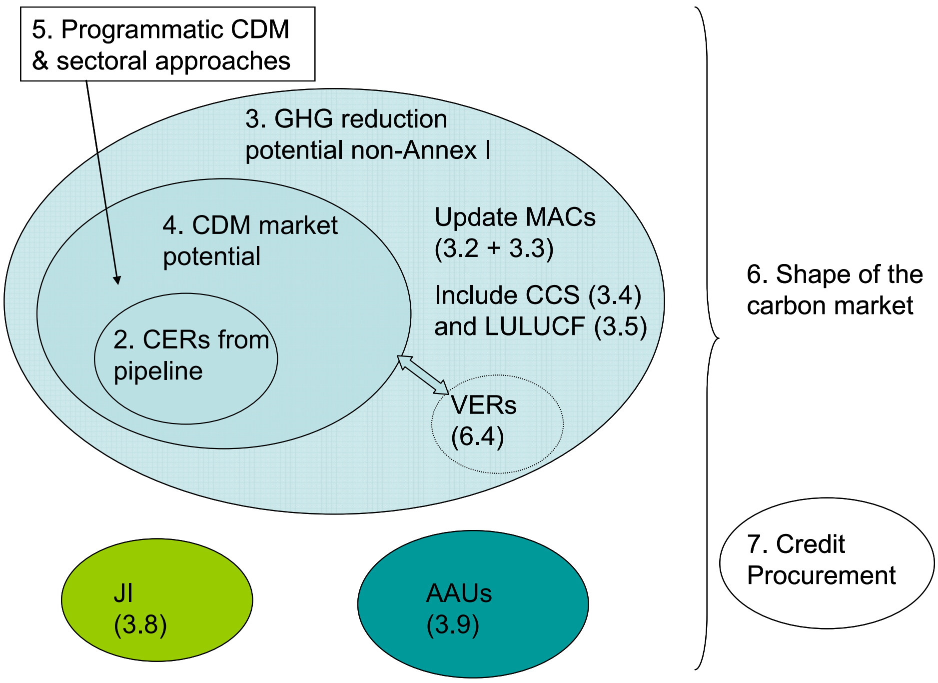

Figure 1.1 *Study structure*

Figure 1.1 shows the approach and structure of this report. Chapter 2 gives an analysis of the current CDM pipeline by two approaches, which will result in insight into the supply of CERs from current and expected projects. Chapter 3 gives an update of GHG abatement potential studies for non-Annex I countries, Russia and the Ukraine, including extension of the data with LULUCF and CCS options. In Chapter 4 the theoretical GHG abatement potential is analysed according to several scenarios related to uncertainties within the CDM in order to reach a likely market potential for CDM projects after 2012. Chapter 5 discusses programmatic CDM and sectoral crediting mechanisms, shedding light on their potential and possible developments. In Chapter 6 we outline possible climate policy scenarios post-2012 (quantitative and qualitative) in relation to carbon trading, to get a better grasp on the possible impacts of political decisions on the role of different types of carbon credits. Chapter 7 includes an overview of different mechanisms to procure carbon credits, followed by the conclusions.

2. CER supply from the CDM pipeline

In this chapter we analyse the expected CDM credits post-2012. This is done using two approaches: 1) the registered projects from the UNEP/Risø pipeline, and 2) the Point Carbon's database on existing and expected projects until 2012. The latter approach includes the first one, but adds projects that are at validation stage (existing projects) and projects that are likely to enter the validation stage before 2012. The CDM project pipeline can thus be divided into three parts, which are dealt with in the two sections of this chapter:

- Registered projects (Section 2.1)
- Projects in validation stage (Section 2.2)
- Projects in pre-validation stage (Section 2.2).

The Point Carbon approach yields a larger CER supply, but also includes larger uncertainties. Its added value is in the expert judgement on expected developments.

2.1 Projections based on registered projects

This section is based on the UNEP/Risø CDM/JI pipeline[1], version September 2007, which includes 803 registered CDM projects. The carbon credits generated by these CDM projects are called Certified Emission Reductions (CERs), with 1 CER equalling 1 tonne of CO_2-eq reduced compared to the established baseline. These 803 projects are generating 168 million CERs (MCERs) per annum, expected to add up to 1,070 MCERs up to 2012. Figure 2.1 shows a technology breakdown of these projects.

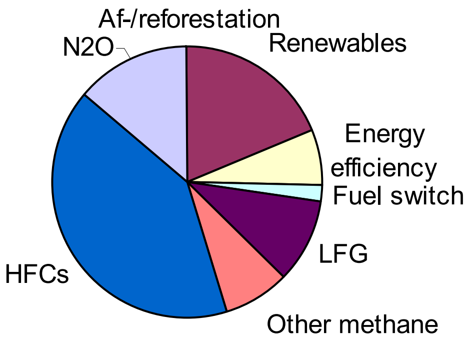

Figure 2.1 *Technology breakdown of registered CDM projects (by expected CER generation)*

Most of these projects will continue to generate CERs after 2012. The quantity depends on the crediting period: if a 10-year crediting period opted for CER generation ends after 10 years (e.g. 2016 for a project registered in 2006). The bulk of the projects (85%) however has opted for the 7-year crediting period with the option of renewing the crediting period twice with an updated baseline, with the possibility of 21 years CER generation (see also Figure 2.5).

The expected CERs up to 2020 cannot be calculated directly, therefore we derive it from estimates for 2030 from UNEP/Risø (2007). The expected CERs, as indicated by the PDDs, from the entire pipeline (i.e. including projects in validation stage) to 2030 are 7.7 billion. The expected CERs from the pipeline up to 2012 are equally divided between registered and

[1] Statistics are also available at the cdm.unfccc.int website, however the available data is not sufficient for the purpose of this chapter.

validation stage projects. Out of the 7.7 billion CERs in the pipeline, 4.8 billion are post-2012 CERs, which included validation and registered projects. Assuming an equal ratio between validation and registered projects this results in approximately 2.4 billion post-2012 CERs for registered projects until 2030, which is on average 133 million per year. In 2012, 168 MCERs are expected from registered projects. Assuming a linearly declining rate the total available amount would be 1.2 billion CERs in the period 2013-2020 from currently registered projects (see also Table 2.1).

Table 2.1 *Post-2012 CER estimation from registered CDM projects*

Projected CERs	Registered CDM projects	Validation stage and beyond
Total CERs up to 2030		7.7 billion (= 7.7 $GtCO_2$-eq reduction)
CERs 2013-2030	ca. 2.4 billion	4.8 billion
Average CERs/yr 2013-2030	133 million/yr	
CERs/yr in 2012	168 million/yr	
CERs 2013 - 2020 (PDD based)	1.2 billion	
CERs 2013 - 2020 (performance adjusted)	0.9 - 1 billion	

However, the amount of credits these projects will actually generate remains uncertain. Based on experience with projects that have already issued CERs, Figure 2.2 shows that many projects generate significantly less credits than expected, but there are also projects that generate more.

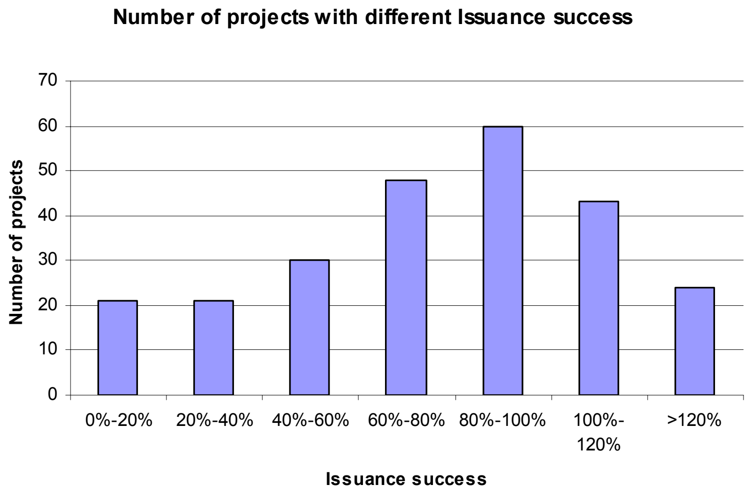

Figure 2.2 *Issuance success of projects for which CERs have been issued as of September 2007*

This is confirmed by Michaelowa (2007), who gives an indication of which technologies are more or less successful. He concludes that the overall performance has been 85%, with geothermal (20%) and landfill gas (30%) significantly underperforming. N_2O projects have been generating more credits than expected. Most of the renewable energy and energy efficiency projects are in the 80-90% range.

Assuming a performance rate of 75-85% the 2013 - 2020 cumulative supply would be 0.9 - 1 billion CERs. The approach and results are summarised in Table 2.1.

2.2 Projections based on existing and upcoming projects

Other than the registered projects (as done in Section 2.1), we check the Point Carbon database of existing and upcoming projects to obtain an estimate of the expected CERs that will be generated.

2.2.1 Existing projects

The methodology for estimation of the CER supply is based on the following assumptions:

- The figures are based on projects currently at public comment period start and beyond (i.e. registered projects + projects at validation stage).
- Projects with a 10 year crediting period will not have their crediting period renewed.
- All projects with a 7 year crediting period will be renewed twice.
- Reductions from renewed projects will lose 10% of their current estimated volume due to potential changes in baseline and new methodologies.
- If the project has been registered, the registration date will function as the crediting period start date.
- If the project has not yet been registered, the projects starting date of the first crediting period (listed in the PDD) will be used as the crediting period start date.
- The projects are risk adjusted according to Point Carbon's methodology on registration risk, performance risk and delay, explained below.

Registration risk expresses the likelihood that the project will not be registered. The registration risk depends on project stage, project type (technology) and host country. The registration risk will be higher for projects at early stages than for more mature projects. When the project is registered, the registration risk will be 0.

Performance risk expresses the risk that the project will generate less (or more) than planned until the end of the Kyoto period. Just like registration risk, performance risk depends on project stage, project type (technology) and host country. Performance risk is based on historical performance data, i.e. the difference between expected volumes and actual issued volumes by project type and country.

Delay: We account for delay by giving all projects a generic delay. In addition, we manually change delay for projects where we have direct information about delay from reliable sources or where the project has not changed its status for a set period of time.

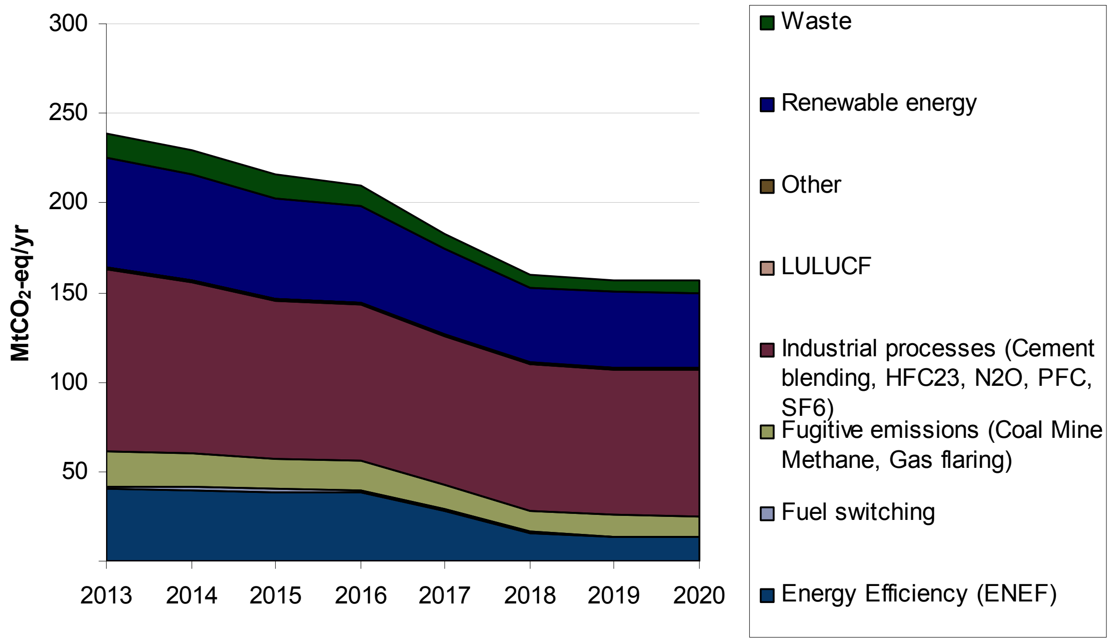

Figure 2.3 *Annual CER supply (risk adjusted) by projects requesting validation and beyond*

Figure 2.2 and 2.3 show that the supply of credits from existing projects decreases from approximately 240 $MtCO_2$-eq/yr in 2013 to 150 Mt/yr in 2020. These figures are higher than those mentioned in Section 2.1 as these also include the projects at validation stage. GHG reduction from industrial processes account for the lion's share throughout that period. CERs from energy efficiency projects significantly decrease after 2016. In the host country distribution China takes over 70%, with India decreasing its share sharply after 2016.

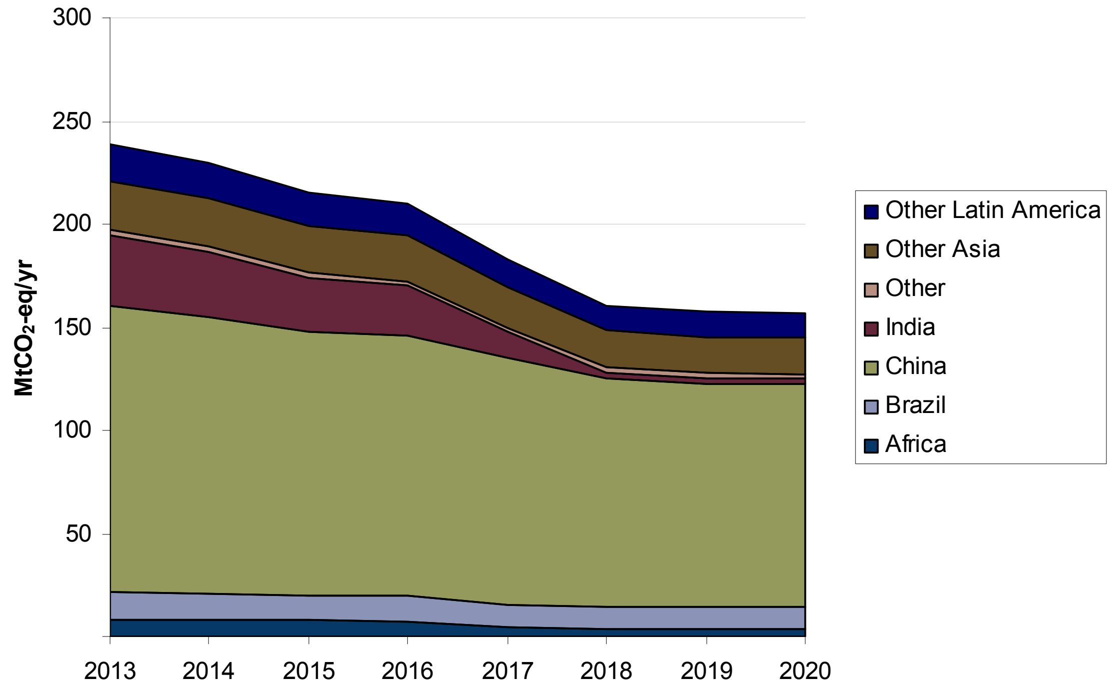

Figure 2.4 *Host country distribution of existing projects, by annual CER supply*

The data for India in Figure 2.4 show a considerable decline in volume from 2013 onwards. India has a higher percentage of projects with a 10-year crediting period compared to other countries. Since you can choose a crediting period of 7 years which can be renewed twice, or one crediting period of 10 years, many projects with a 10-year crediting period will end in the time-period 2013-2020 (as shown in the figure below). In our assumptions, we assume that all projects with a 7-year crediting period will renew their crediting period (with a 10 per cent decrease of estimated volume due to potential changes in baseline and new methodologies). Thus India represents a higher share of the light blue area in the Figure 2.5, compared to other countries.

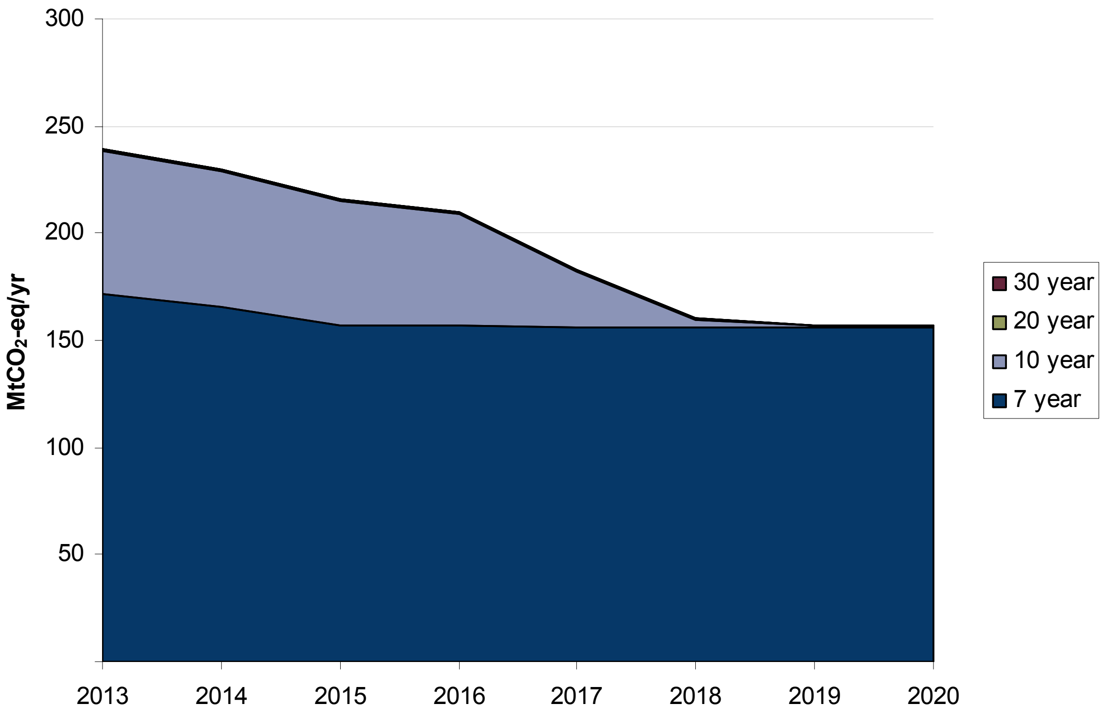

Figure 2.5 *Volume of annual CERs from all existing projects, risk adjusted, differentiated by length of crediting period*

2.2.2 Upcoming projects

Upcoming projects are projects that have not reached public comment period start or have indeed not been planned yet. The 'upcoming' projects include all the PINs or prospect PDDs on Point Carbon's database. To find out how many new upcoming projects we can expect in the future, we use historic inflow data, i.e. we assess how many projects within project type x came into the pipeline (publicly available) over the last year. Then we perform an inflow adjustment; i.e. we ask if this inflow can be expected to continue, be reduced or increased, based on general and project specific factors, based on the assessment of e.g. current policies, investment climates and likely uptake of main project types in the main countries. The volume of CERs is discounted using the empirical evidence of performance etc. from existing projects.

General inflow adjustment factors are factors that will affect the inflow of all project types (more or less) in the same way. Examples could be:

- Post-2012 (will there be a post-2012 regime?)
- Demand/supply balance (what is the demand compared to supply?)
- Regulatory (generic CDM Executive Board factors such as will they receive enough funding so they can register projects and issue credits without delays?)

Project specific inflow adjustment factors - are factors that will affect the inflow of one project type. Examples could be:

- Technical factors (e.g. remaining technical potential, managerial awareness etc.).
- Economic factors (e.g. project cost versus expected future and CER/ERU price at the time of decision to build etc.).
- Political factors (e.g. project specific decisions from national governments, the CDM EB, or the COP/MOP).

Additional assumptions:

- In our opinion the number of LULUCF projects that will enter the pipeline before 2012 will be limited.
- Much of the volume (especially of HFC23 and N_2O in adipic acid production) has already been taken up and is thus represented through the existing volume. There is a limited additional technical potential to many of the industrial processes projects (except for following).
- A potential inflow of ‘new HFC23’ has not been taken into account due to the major uncertainties on including ‘new HFC23’ into CDM pre-2012 (see also Section 3.3).

Figures 2.6 and 2.7 show how much volume we expect from projects starting pre-2012, but do not include projects that will start post-2012. All upcoming projects are expected to generate reductions at least until 2020.

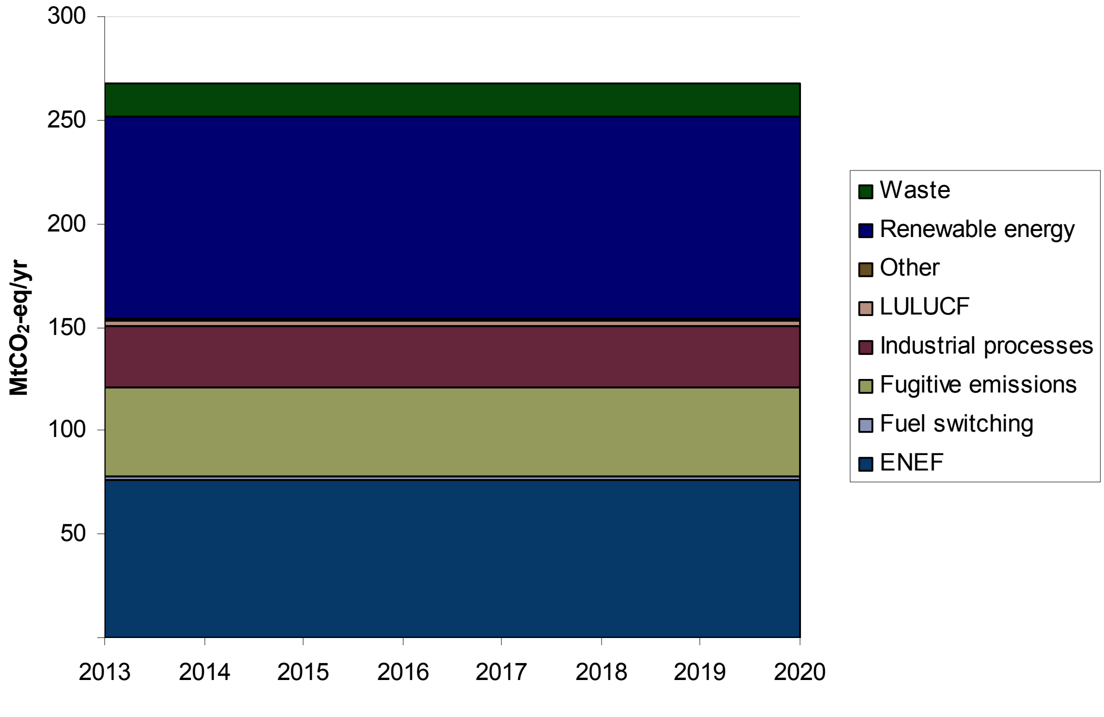

Figure 2.6 *Annual CER supply from expected CDM projects before 2012*

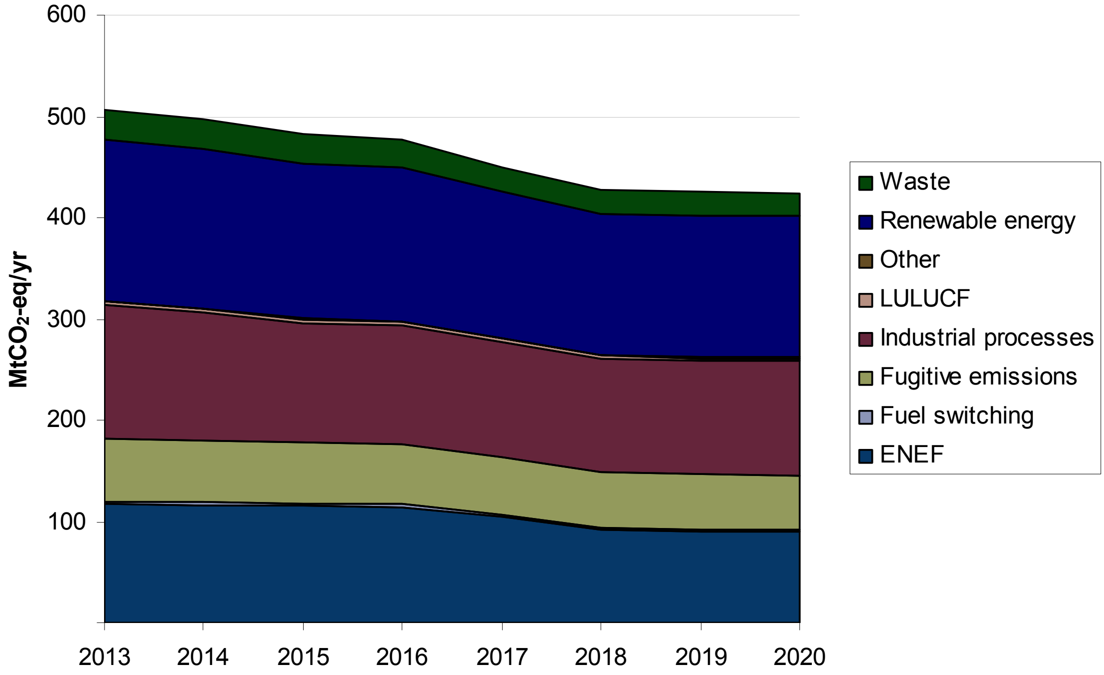

Figure 2.7 *Annual CER supply by existing and upcoming projects*

Assumptions are necessary since this is an estimation of future supply. The assumptions may seem optimistic, since we assume that all projects with a 7-year crediting period will be renewed. The assumption is based on the view that all project developers will behave as rational economic actors, i.e. if they can make money by renewing their crediting period, they will do so.

Figure 2.7 shows the expected CER supply from existing projects and upcoming projects until 2012. A number of observations can be made:

- The overall supply in 2013-2020 is on average approximately 450 $MtCO_2$-eq/yr.
- Fugitive emission reduction, energy efficiency and renewable energy increase significantly compared to the figure for the existing projects only; industrial emission reductions increase by less than 30 Mt/yr.
- LULUCF is not expected to play a role.

We would argue that the estimated supply 2013-2020 is realistic but conservative, for the following reasons:

- The total supply expected from 2013-2020 is based only on projects that have started (or that we expect to start) before 2012. The estimate does not take into account projects that will start in the period 2013-2020.
- The delivery from renewed projects is reduced by 10% from their current estimated volume due to potential changes in baseline and new methodologies.
- The total supply expected in 2013-2020 does not take into account new project types that might arise in this period (e.g. CCS, avoided deforestation etc.).

In summary the estimates of the CER supply (110 - 450 million per year on average, or 0.9 - 3.6 billion cumulative over 2013 - 2020) in this chapter give an indication of the credits that ongoing CDM projects are likely to generate, with the low estimate referring to the most certain projects, and the high estimate including more uncertain projects. In the following chapters we will focus on the total potential for carbon credits, which is obviously significantly larger.

3. Technical and economic abatement potential

In Chapter 2 we analysed the projected GHG reduction from CDM projects currently in the pipeline or under development. The total potential for emission reduction is obviously much larger. In this chapter we give an overview of the potential for greenhouse gas reduction in non-Annex I countries (of which the estimates in Chapter 2 are part), Russia and the Ukraine, as well as a brief discussion on possible trading of Assigned Amount Units. For the non-Annex I regions, a basic description is given of the approach followed in earlier studies and new work on the inclusion of non-CO_2 GHGs, CO_2 capture and storage and Land-use, land-use change and forestry, while the annexes to this report provide a more elaborate explanation.

The following definitions are used:

- Technical potential: what emission reductions can be realised based on technical and physical parameters, e.g. the wind energy potential in a country.
- Economic potential: what emission reductions can be realised below a certain cost level in €/tCO_2-eq.
- Market potential: what emission reductions can be realised taking into account barriers, such as social adoption of technologies, legal and regulatory barriers, information problems, etc. (further investigated in Chapter 4).

3.1 Starting point: TETRIS database

In the TETRIS project[2], marginal abatement cost curves (MACs) for the non-Annex I region have been developed (Wetzelaer et al, 2007). The MACs are based on national abatement cost studies in 30 countries and include a large set of options in all sectors. The curves were aggregated in order to estimate the technical and economic potential for GHG reduction in 2010. The GHG emissions of these 30 countries cover ca. 80% of the total non-Annex I regions emissions. Therefore a factor of 1.25 was used to extrapolate the results for 30 countries to the entire non-Annex I region. Transaction cost related to the project cycle of CDM projects were added according to different technology groups, between 0.2 and 0.7 \$/tCO_2-eq. Other (non-economic) barriers were not taken into account.

It was concluded that the reduction potential for options up to 20 \$/tCO_2-eq is approximately 2 GtCO_2-eq/yr in 2010. A significant part of this, more than 0.7 Gt/yr, could be abated at negative cost, and 1.7 Gt/yr up to 4 \$/tCO_2-eq. China and India take up 60% of this potential.

The authors note that these results should be viewed with caution due to a number of limitations to the study, of which the most important are:

- The country studies use different methodologies and assumptions which make the results from these study not completely comparable.
- Most of the country studies were published before the year 2000.
- The country studies are not exhaustive in the GHG reduction options that are considered. The TETRIS study is mainly about CO_2 reduction technologies. Of the other GHGs, only a limited number of methane abatement options are taken into account. LULUCF, clean coal technologies, CO_2 capture and storage and biofuels are not included.

The abatement cost figures were translated to 2006 price levels by using price index developments of the US\$ and calculated into € using an exchange rate of 1.2 \$/€.

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2 Technology Transfer and Investment Risk in International emission trading, carried out by ECN and several other European research organisations (see also http://www.zew.de/en/kooperationen/UMW/TETRIS/index.php).

3.2 Update and extrapolation

In order to make optimal use of the data gathered in the TETRIS project for the current study, i.e. the abatement potential post-2012 in developing countries, we have extrapolated the data to 2020 and included options that were not taken into account in the previous study.

As GHG emissions rise in most countries over time, the potential to reduce these emissions also increases. To extrapolate the MACs from 2010 to 2020, we retrieved the figures for 2020 in the original country studies for a number of important countries and options. For the other options the potential figures were multiplied by the expected growth of CO_2 emissions between 2010-2020 for the relevant region, as projected in the World Energy Outlook 2006 (IEA, 2006).

In addition, a limited number of recent studies provide updated figures for options in India (CCAP/TERI, 2006) and China (CCAP/Tsinghua Univerisity, 2006). However overall data availability has turned out to be a limiting factor. For example, no data on the biomass potential and abatement cost for India have been found.

3.3 Non-CO_2 GHGs

Inclusion of non-CO_2 options in the MACs has been performed by using data from a recent and extensive study carried out by the US Environmental Protection Agency (USEPA, 2006). It provides country or region specific cost information for a large range of non-CO_2 options. The abatement cost figures for the options are given in classes of 15 \$/tCO_2-eq between 0 and 60 \$/tCO_2. This resolution can result in an overestimation of the actual cost, as in our database we took the upper limit of the cost classes provided in the study, e.g. 15 \$/tCO_2-eq was taken for all options in the cost class between 0 and 15\$/tCO_2-eq. For options with a large potential we therefore made a better estimate by reading figures from the abatement curves included in the report. See Annex I for an elaborate description of the US EPA report and its use for the current study. Overall the data are considered suitable for this study.

For estimation of the potential of the abatement potential of HFC-23 from HCFC-22 production additional information was used from Cames et al (2007), the IPCC/TEAP Special Report on Ozone and Climate (IPCC/TEAP 2005), and Point Carbon (2007a), to account for differences in HCFC-22 for feedstock and non-feedstock and the recent decision to realise an earlier phase-out of HCFC-22 in developing countries. The total abatement potential therefore is 119 MtCO_2-eq/yr in 2020, of which 47 from new plants. For an elaborate description of the approach, see Annex I.

The overall potential for the non-CO_2 options in 2020 is 1.52 GtCO_2-eq/yr, of which 1.3 Gt/yr consists of various methane reduction options, notably landfill gas capture, coal mine methane, manure management, oil and gas production, methane capture and agriculture options. Cames et al (2007) arrive at a landfill gas (LFG) potential of 654 MtCO_2-eq/yr in 2020, which is twice the potential identified in USEPA (2006). For the other methane options no figures for comparison have been found.

3.4 Inclusion of CO_2 capture and storage

At COP/MOP 2 in 2006 a UNFCCC process was started that should lead to a decision on the eligibility of CO_2 capture and storage (CCS) projects under the CDM during COP/MOP 4 in 2008. Opinions among stakeholders, scientific community and policymakers on this question differ strongly. Two CCS projects with new baseline and monitoring methodologies have been submitted to the CDM Executive Board in 2004. These made clear that there are several issues that need to be resolved, including monitoring standards, liability for long-term monitoring, and taking seepage into account. In addition there are concerns that including CCS under the CDM would divert investments in the power sector towards fossil fuels rather than renewables, and the lack of sustainable development benefits of the technology, compromising the second goal of the CDM.

Awaiting the decision on eligibility of CCS under the CDM, we made a first estimation of the cost and potential of the technology (see Appendix B for a detailed description of the methodology). Given the current status of CCS as a demonstration technology in industrialised countries, CCS is not expected to play a large role in developing countries before 2020 and therefore we have looked at the 'early opportunities', which are industrial sources where CO_2 is produced in a relatively pure stream. For this option the CO_2 capture stage in the CCS chain is cheaper compared to less pure sources. The following were considered[3]:

- Ammonia production
- Ethanol production
- Ethylene oxide production
- Hydrogen production.

In addition two options for newly built power plants were taken into account, as the power sector is where CCS is expected to play the most important role

- New coal-fired power plants
- New gas-fired power plants.

Other options are more expensive, or will not be at the right stage of development in the appropriate timescale and are not expected to play a significant role up to 2020. Natural gas processing may also be a good source of CO_2 for CCS by 2020, however there is insufficient data available to calculate the potential from this type of activity at this point.

The potential for CO_2 capture from these sources in 2020 was assessed for nine large non-Annex I countries, Russia and the Ukraine. The capture cost for the industrial sources with pure CO_2 streams was assessed to be € 5/tCO_2 captured and for coal and gas-fired power stations € 30 and € 40 /tCO_2 respectively. Transport and storage costs were also added, taking up only a small share of the total abatement cost. In terms of potential, two main considerations have been taken into account. Firstly, the capture efficiency is assumed to be 85%. Secondly, the uptake of CCS is not likely to represent the full amount of gas available. We have, therefore, used a scenario under the assumption of 0% CCS built in 2015 and after that linearly increasing to 50% of the newly built power plant potential and 70% of the point sources of pure CO_2 in 2030, a scenario also used in Hendriks (2007). In 2020 therefore only a smaller fraction represents the potential (23% for industrial sources and 12% for power plants on average, but differentiated by geographic region)

Based on this methodology the CCS potential for non-Annex I countries in 2020 is estimated to be 43 MtCO_2/yr for industrial sources (mainly ammonia production), 93 MtCO_2/yr for newly built coal-fired power plants and 28 MtCO_2/yr for gas-fired power plants up to a cost of 50 €/tCO_2-eq. This could be an underestimation because of 1) exclusion of the significant early opportunities for natural gas processing, and 2) the use of scenarios for penetration of CCS in power plants. Our estimate can therefore be regarded as a conservative realistic economic potential for 2020. Given the current demonstration phase of the technology this can be justified. Further delay in the implementation of the demonstration projects in Europe, and the appropriate policy framework for CCS under the CDM will only further decrease the potential for CCS before 2020. However, a more enabling framework for CCS could lead to higher figures than the realistic potentials presented here.

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3 CO_2 from natural gas processing is also considered as an 'early option' for CCS but is not included here due to lack of data.

3.5 Land-use, land-use change and forestry

Currently the only eligible project activity under the Clean Development Mechanism (CDM) of the Kyoto Protocol in this category is afforestation and reforestation. Another activity with a lot of potential, but not yet eligible under the Kyoto Protocol is avoided deforestation. In the ongoing post-2012 climate regime negotiations there is debate regarding whether or not and how to include avoided deforestation in the protocol. We disregarded other land use change activities in this study, because these activities still pose a lot of problems regarding availability of data and methodologies. Thus we focus on avoided deforestation and afforestation/reforestation in our abatement calculations.

Our methodology has been discussed with Mr. Bas Clabbers, senior policy maker and sink expert of the Dutch Ministry of Agriculture, Nature and Food Quality and Mr. Gert-Jan Nabuurs, senior researcher European forest scenario studies at Wageningen University and Research Centre and Coordinating Lead Author of Chapter 9 on Forestry of the IPCC Fourth Assessment Report.

We calculated potentials in the world based on 30 countries with the largest forest cover in hectares extended with six countries with considerable potential for afforestation/reforestation. With this approach we cover around 90% of total forest cover in the relevant countries for this study. For avoided deforestation we were able to add the remaining relevant potential at continent level, for afforestation/reforestation this information was not readily available.

In Table 3.1 the results of our calculations, the data used and the basic assumptions in the calculations are presented. It should be stressed that in estimates for emission reductions through forestry, uncertainties remain very large. Therefore we use two different approaches in order to yield a technical potential and more realistic potential, which is further considered to be the market potential (further used in Chapter 4). The latter estimate is considered to be the most realistic as the assumptions therein are a better reflection of real-life conditions. See Appendix C for elaborate explanations of our calculations and the detailed results per country.

Table 3.1 *Technical LULUCF CO_2 reduction potential in non-Annex I countries.*

Activity	Technical potential ($GtCO_2$/yr in 2020)	Market potential ($MtCO_2$/yr in 2020)
Avoided deforestation	2.3	55 - 353
Afforestation/Reforestation	7.6 - 9.0	74 - 235

Note that the technical potential for emission reductions from avoided deforestation in 2020, presented in the table above, was calculated by estimating the total amount of hectares between 2012 and 2020 that are not deforested in comparison to the expected business as usual (BAU) deforestation in this period.

3.5.1 Avoided deforestation

The source for world forestry data used is the Forest Resource Assessment (FRA) by the FAO, latest published in 2005[4]. The amount of CO_2 that can be stored per hectare of forest in a certain country is based on the IPCC LULUCF Good Practice Guidelines. Costs are calculated based on the same source as the Fourth Assessment Report of the IPCC (Grieg-Gran, 2004).

In the estimate for technical potential it is assumed that deforestation trends until 2020 will follow an extrapolation of the known trends from 1990 to 2005. The potential for avoided

4 Forest definition: minimum of 0.5 ha of wooded area, canopy of 10%, productive plantations for industrial purposes excluded.

deforestation is the difference between CO_2 stock in existing forests in 2012 and the extrapolated CO_2 stock in forests in 2020.

In order to calculate the low estimate for the technical potential three scenarios were constructed and calculated:

- Scenario 1: The Coalition of Rainforest Nations plus Brazil and Indonesia are the only countries that will have necessary policy and monitoring systems in place to make use of the possibility to reduce emissions under an avoided deforestation scheme in the period from 2012 to 2020. These countries will reduce deforestation in 2020 by 25% compared to their baseline deforestation.
- Scenario 2: Brazil, Indonesia and Papua New Guinea are front runners in which implementation is expected to be more realistic than in the others. Thus we take only the avoided deforestation in these countries into account.
- Scenario 3: As in Scenario 2, but only 5% of deforestation can be avoided.

The costs of abatement of CO_2 emissions through avoided deforestation were set at the mean of the range 484-1,050 USD/ha for all countries in this study. These are rather rough calculations. More research would be necessary to refine these cost data, however this was not possible within the scope of this study.

3.5.2 Afforestation/ Reforestation

The basis for the calculations of areas theoretically eligible for afforestation or reforestation as defined under the CDM are the data from ENCOFOR[5]. The calculations of area realistically eligible for afforestation or reforestation are based on the current world plantation growth rate in the FRA 2005.

The Encofor database needs input for forest definitions (canopy cover) per country. The canopy cover definition determines the amount of land available for afforestation/reforestation in a country. National CDM forest definitions set by the DNAs of the 36 selected countries were used. For countries that did not yet set their forest definition, we assumed two scenarios:

- In Scenario 1 we assumed a canopy cover definition of 10% for countries that had not yet set their CDM forest definition. This is the lowest value in the UNFCCC range.
- In Scenario 2 we assumed a canopy cover of 30% for these countries that have not yet set there CDM forest definition, being the maximum value in the UNFCCC range.

The potential of CO_2 sequestration is calculated by assuming a global average annual growth rate of 4 tonnes C per hectare[6] (14.7 tonnes CO_2 per hectare) multiplied with the amount of hectares determined with the Encofor tool. We did not distinguish in growth rates per country or type of forest.

For the market potential for the area that can be used for afforestation/reforestation by 2020, we assumed that the current growth rate of forest plantations (1%) is regarded as business as usual. Changes due to CDM are calculated in three different scenarios:

- an increase of business as usual growth rate to 1.5%,
- an increase to 2%,
- an increase to 2.5%.

The increase in hectares of plantations due to CDM is multiplied with the global annual growth rate of 14.7 tonnes CO_2 per hectare to arrive at the total amount of CO_2 sequestered in 2020.

[5] Environment and Community based framework for designing afforestation, reforestation and revegetation projects in the CDM: methodology development and case studies (ENCOFOR) http://www.csi.cgiar.org/encofor/forest/index_res.asp

[6] Reasonable according to Mr. Gert-Jan Nabuurs

The cost of afforestation or reforestation are assumed to be approximately 1350 USD per hectare for tropical wet regions, 675 USD per hectare for tropical dry regions and 4000 USD per hectare for temperate or boreal regions, only including labour costs and costs for planting stock. Again this is a rough calculation. Further research would be needed to refine the cost data.

3.5.3 Other land use change

Other activities that could lead to emission reductions are improved forest management, stopping drainage of peat lands for agriculture and forestry and improved tillage in agriculture to increase the carbon content in soil. None of these activities are currently eligible under the CDM, nor are they expected to become eligible and producing certified emission reductions by 2020. For this reason this potential has not been investigated further.

3.6 Review by regional experts

In the course of this study we have sent the preliminary findings on the abatement potential, including the new options CCS and LULUCF to research institutes with excellent knowledge of energy and climate issues in various non-Annex I countries for their expert review:

- China: China Renewable Energy Industries Association (CREIA).
- Rest of Asia: IT Power India.
- Africa: Environment and Development Action in the Third world (ENDA, Senegal).
- Latin America: the Center for Integrated Studies on Climate Change and the Environment (Centro Clima, Brazil).

According to the reviewers the abatement cost and potential data in the TETRIS project and the update carried out reflect the most up to date knowledge. The reviewers also included a limited set of additional options, which are included in Appendix D. Some of these did not include abatement cost figures, and therefore these options could not be taken into account in the MACs. They could however represent a significant abatement potential, in particular for wind and biomass energy. For e.g. India, IGES (2005) estimates 19.5 GW biomass power potential and 45 GW wind power potential after 2010, translating in 94 Mt and 90 $MtCO_2$-eq/yr reduction respectively, which compares to the 29 Mt/yr for wind which is currently included in the database.

For Brazil a very good overview of policies and additional literature sources for LULUCF was provided, which is discussed in Appendix C. In Section 4.1.5 an overview of regional policy goals is given, for which the reviewers have provided significant input.

3.7 Overall results

Based on the preceding analysis, Figure 3.1 shows the technical GHG abatement potential in non-Annex I countries per year in 2020, broken down by groups of technologies. They are the result of the bottom-up approach as explained in Section 3.1 to 3.3. For afforestation/re-forestation, avoided deforestation, and CCS a more general, region-specific approach was followed, including a set of assumptions regarding general uptake of technologies (see Section 3.4 and 3.5). Therefore the bars of these options are shown in a different colour.

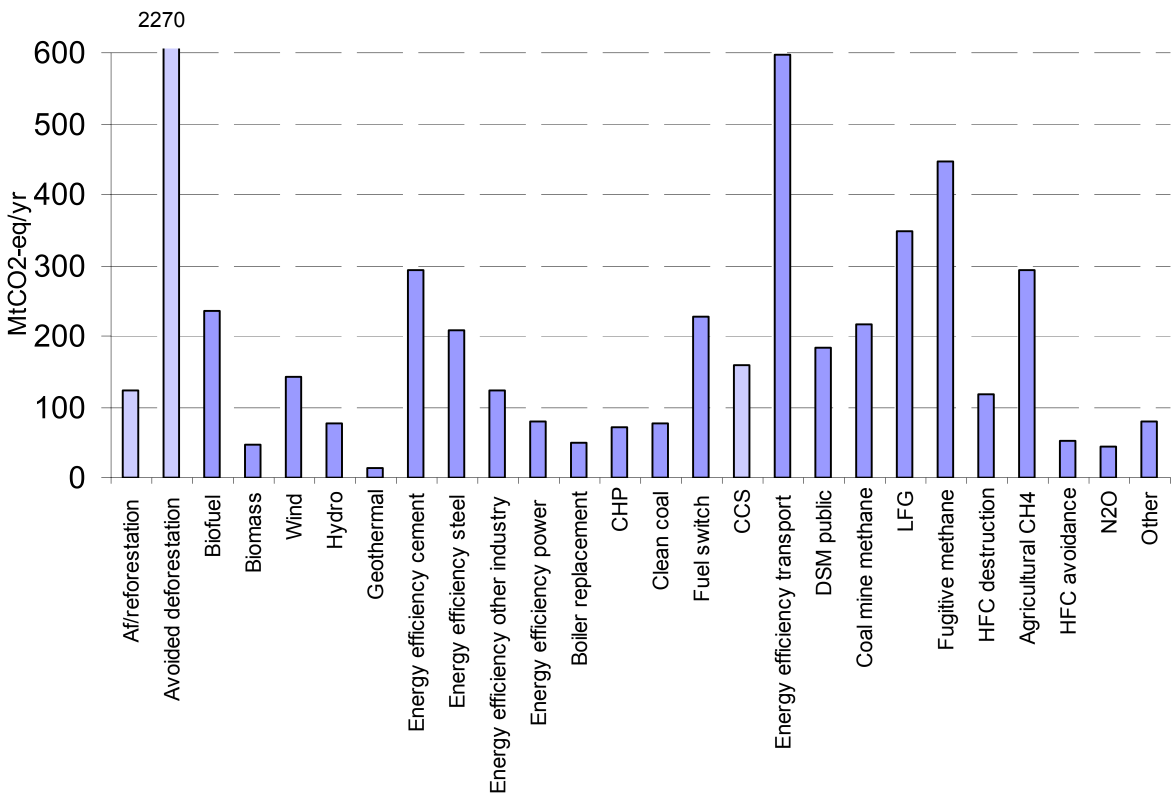

Figure 3.1 *Technical abatement potential in 2020 by technology.*

Figure 3.2 incorporates the cost of the technologies into a marginal abatement cost curve for 2020 for non-Annex I countries. Due to the large potential (2.3 $GtCO_2$/yr) of avoided deforestation and the large uncertainties therein (see Section 3.5) the scale in Figure 3.1 is adapted to the second largest option, and in Figure 3.2 two MAC curves are shown: one without AD and one including AD.

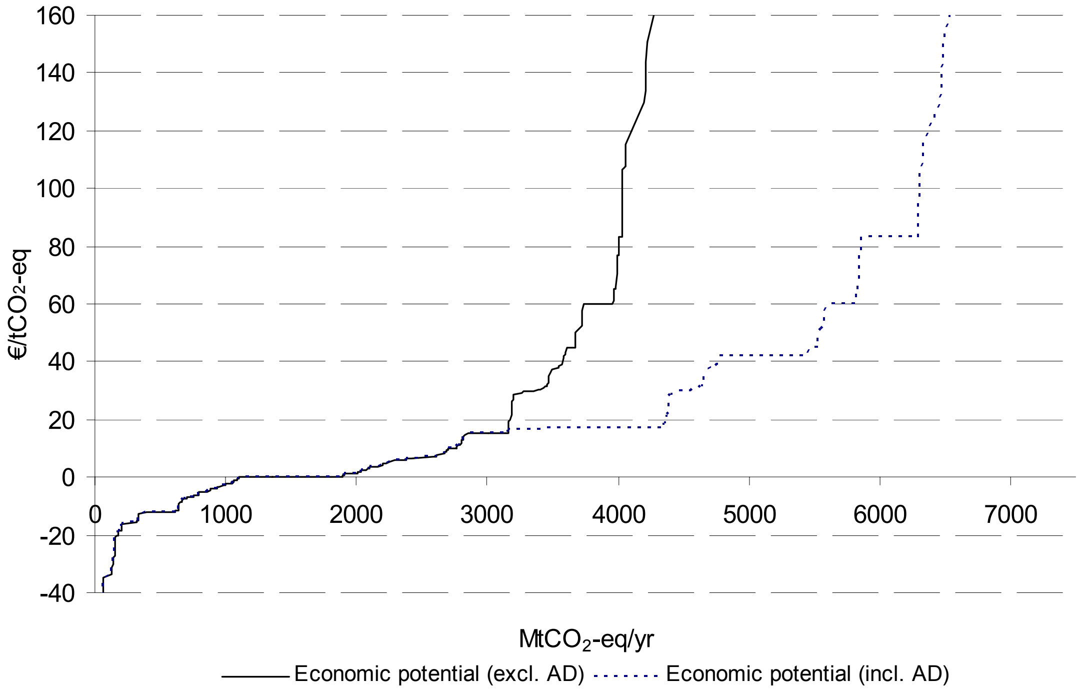

Figure 3.2 *MAC curve for non-Annex I countries in 2020.*

From the graphs the following observations can be made:

- The technical abatement potential in 2020 is approximately 4.3 $GtCO_2$-eq/yr; if avoided deforestation is included 6.6 $GtCO_2$-eq/yr.
- The economic abatement potential up to € 20/tCO_2-eq is more than 3.2 $GtCO_2$-eq/yr (with avoided deforestation 4.3 Gt/yr).
- More than 1.5 $GtCO_2$/yr can be reduced at zero or negative cost[7].
- Energy efficiency and methane options take up more than half of the total potential; avoided deforestation may outstrip the potential of other options, taking into account the very large uncertainties.
- There are several options that would benefit from further examination, notably biomass and fugitive methane reduction options, as they might be under or overestimated. Also the potential of avoided deforestation deserves further examination.

These data were reviewed and supplemented by regional experts in order to assure optimum use of existing sources. In Chapter 4 the CDM market potential will be analysed using the MAC curve and scenarios for developments within the CDM. Also the results are compared with other studies on the abatement potential.

3.8 JI potential post-2012

The GHG abatement potential in the Ukraine and Russia is likely to be significant also, as we can observe from Figure 3.3. The MAC curve in this figure was constructed from the abatement cost data developed by the Centre for Clean Air Policy in the TETRIS project (Schmidt et al, 2006). Data from the GAINS model developed by IIASA were used, and include over 200 climate mitigation options for the two countries for the year 2010. In this case we have assumed the potential for GHG reduction in 2020 to be similar to that of 2010. Extrapolation by GHG

[7] The occurrence of options with negative cost (also called no-regret options) is a common finding in many bottom-up abatement cost studies: even though from a national cost perspective these seem to be cost-effective, there are other barriers that prevent uptake of these technologies. For a discussion on these barriers and whether these options can still be additional we refer to Chapter 4.

emission factors, as was done for non-Annex I countries, would not be appropriate, as policies that harness some part of the potential are likely to be in place up to 2020. However the significance of these policies may be limited, as according to the CCAP MAC the no-regret potential is small for Russia and the Ukraine. It should be noted that cogeneration options are excluded in the CCAP study, which are options that could have a significant potential. Discount rate used is 4%, which is a lower figure than most other studies use (8-10%). For Russia only the part west of the Ural Mountains is included, which covers the major part of the population.

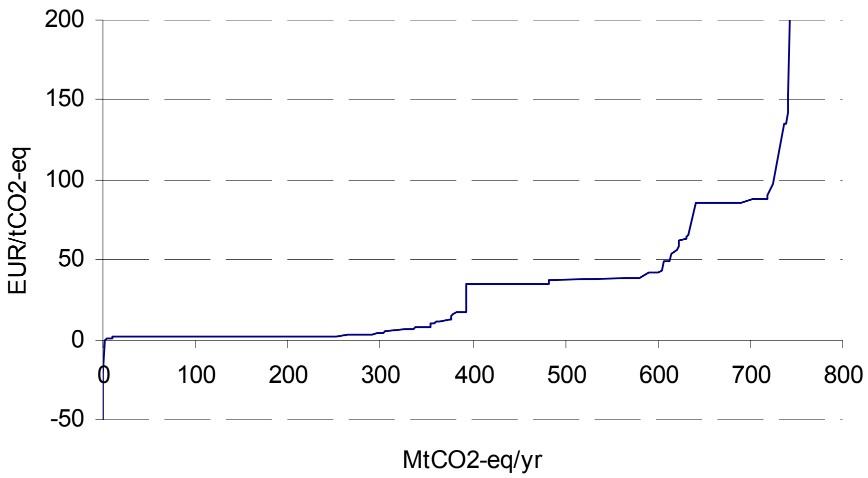

Figure 3.3 *Economic GHG abatement potential in Russia and the Ukraine in 2020*

Over 600 $MtCO_2$-eq/yr can be reduced at cost lower than € 50/tCO_2-eq. Russia takes up more than 80% of the potential. Methane reduction options, in particular from leakage in natural gas pipelines, represent more than 80% of the potential below € 20/tCO_2, while the CO_2 reduction options are generally more expensive. It is possible that options that are excluded from the analysis, such as cogeneration, provide additional low-cost CO_2 reduction.

This economic potential for GHG reduction can be harnessed by implementing Joint Implementation (JI) projects. The Russian government adopted guidelines for approving JI projects in September 2007 and is now aiming to have its Track 1 methodology approved in the first quarter of 2008, in which case the JI projects can be implemented without external supervision. For JI in the first Kyoto commitment period, Korpoo (2007) has provided an analysis of the projects submitted to the JI Supervisory Committee up to September 2007 (JI Track 2 projects). These are 38 and 15 in number for Russia and the Ukraine, respectively, and abating 17 and 8 $MtCO_2$-eq/yr on average over 2008-2012. The analysis of these projects generally tally with MAC presented in Figure 3.3: methane options take the largest share of the project portfolio, with energy efficiency and renewables representing smaller but significant shares.

The scope for JI-type projects after 2012 relies on a number of factors[8], many of which are difficult to define in the absence of a known post-2012 international agreement on greenhouse gases. The key factors determining the availability of greenhouse gas reducing projects in Russia and the Ukraine will be:

- The scale of any commitments under an international regime, in relation to baseline emissions.
- The availability and costs of greenhouse gas reduction option.

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8 In Chapter 4, a more quantitative analysis for CDM projects is provided that give insight in the importance of factors. For JI the overall potential is much lower, and only a qualitative argument is provided here, as a full quantitative analysis is outside the scope of this study.

- The existence of mandatory regulation that could render any projects non-additional.
- Institutional capacity to develop and approve JI projects.
- Other political factors.

Commitments under an international regime
If commitments under an international regime are tightly aligned to national BAU, the scope for JI projects will be limited, as governments themselves will have to grasp all available greenhouse gas reductions in order to meet their international targets. It may be safe to assume that any future international schemes will be careful not to purposefully create 'hot-air' (see also Section 3.8) and therefore also opportunities for JI in Russia and the Ukraine could be limited, but are still likely to be significant.

The availability of greenhouse gas reductions
Looking ahead to the period post-2012, a large number of emission reduction projects in the Ukraine and Russia are still likely to be possible. The MAC curve in Figure 3.3 includes a large number of potential greenhouse gas reduction measures, all of which are considered broadly possible. The areas that are considered the most important in the near future will be energy efficiency, including renewable energy options, particularly in industry as well as non-CO_2 gases, and gas leakage.[9] It should be noted that the CCAP MAC curves tend to focus mostly on non-CO_2 sources, and it is possible that further potential savings relating to e.g. energy efficiency are not captured. However, projects using these savings would also have to be additional to any national energy efficiency programmes.

The Ukranian National Ecological Investment Agency (NEIA) will be targeting its investments in the following sectors:
- heat supply
- housing and public utilities
- wind
- waste water
- agriculture
- biofuel
- coal mines.

Such investments in the period 2008-2012 could reduce the supply of available emissions reductions in the post-2012 period. However, estimates of the scale of reductions expected from these projects are not yet available.

Other national policies[10]
The existence of national policies to reduce greenhouse gases, both in 2008-2012 and after 2012, will also be key in determining what type of projects might be possible, and where greenhouse gas reductions will still remain.

Currently, there are few greenhouse gas reducing policies in Russia although there are some energy efficiency policies within the National Energy Strategy and particular programmes for industry to improve its energy efficiency. There is a federal target in the Programme for an energy efficient economy for 2002-2005 which includes an outlook to 2010. This programme includes some goals for transport, including the need to increase the use of biofuels. Policies are limited in the domestic sector and there are limited policies to promote environmentally-friendly agricultural practices.

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9 Informal discussions with project developers in Russia and the Ukraine indicate that the measures are reasonable. No technical review of the numbers has been carried out.

10 Information gathered from National Communications and other national sources.

Some particular national policies are important already in terms of current JI project development. For instance, it is mandatory in Russia to flare associated CH_4 in oil production. As a result, projects relating to this methane source must go beyond flaring and move towards energy use. The way in which Russia deals with this policy in the first Kyoto commitment period will make it clearer how any projects post-2012 will be affected.

In the Ukraine, there is a slightly greater amount of climate policies already in place and, as mentioned above, investments from the NEIA will be important in the period leading up to 2012, influencing the potential savings after 2012.

For example, Ukraine's ongoing efforts to improve energy efficiency across the economy will reduce greenhouse gas emissions even as the economy grows; there are planned increases in nuclear power capacity that are also likely to reduce emissions. On the other hand, the Ukraine is also expanding the use of domestic coal as an energy source. There are some policies in place in relation to renewable energy, CHP development and clean coal. The net result of these developments will determine future greenhouse gas emissions.

On the transport side some technology-related policies exist as well as policies for biofuels and the increase in the use of rail transport.

Other political factors
The most significant factors relating to Russian projects at the moment are underlying political issues. Currently the involvement of government monopolies in the energy and gas sectors, and government involvement in projects themselves are a significant obstacle for project investors. The 2008-2012 period will indicate whether any of these barriers will be addressed adequately.

3.9 Role of Kyoto AAUs beyond 2012

A number of Annex I countries, particularly in Central and Eastern Europe, Russia and the Ukraine, are on their way to emit less GHGs than their commitments under the Kyoto Protocol. These excess Assigned Amount Units (AAUs) can be sold to other countries short of their target under International Emissions Trading, the third flexible mechanism under the KP. In Cames et al (2007) a number of studies that assess the potential supply of excess AAUs ('hot air') in the Kyoto period are reviewed. The estimates are in the range between 689 and 1500 $MtCO_2$-eq/yr in 2010, with an average of 990 $MtCO_2$-eq/yr. If this figure is aggregated across the five years of the first Kyoto commitment period we obtain an indicative estimate of 5.0 $GtCO_2$-eq cumulatively.

A World Bank report[11] quoted a surplus for the Ukraine of roughly 1-2 billion AAUs (equal to 1-2 $GtCO_2$-eq cumulative reduction) for the first commitment period (2008-12)[12]. The Ministry of Economy estimates this surplus to be 2.225 billion AAUs and plans to sell 50% of this during the first commitment period (Point Carbon, 2007c). With a recent change in government however this becomes uncertain.

The Ukraine intends to set up a Green Investment Scheme (GIS) and already has plans in place for the structure and operation of such a scheme. Under this scheme the National Ecological Investment Agency (NEIA) would be responsible for sales of Kyoto credits. The funds from these activities would then be re-invested in part in greenhouse gas reducing schemes within the Ukraine. The choice of investment would be informed by their economic value and the potential

11 Ukraine options for designing a Green Investment Scheme Under the Kyoto Protocol; Sustainable Development Department Europe and Central Asia Region, World Bank, September 2006.

12 Estimates from the Second National Communication of Ukraine and from the 'The National Strategy of Ukraine for Joint Implementation and Emission Trading', from the Ministry of Environmental Protection of Ukraine.

to reduce greenhouse gases, amongst other factors. It should be noted that a well-functioning GIS requires considerable institutional capacity.

It is likely that a certain part of the overall AAU surplus will be traded and used by other Annex I countries to comply with their Kyoto targets (Point Carbon, 2007c), e.g. by using a GIS, which ensures that the revenues from selling the AAUs are used for climate change mitigation. However these AAUs can also be banked by the countries that own them and can then be traded (or used for compliance) after 2012. The banked AAUs can therefore play a significant role after 2012, depending on 1) how many will be traded in the first commitment period, 2) under what conditions they can be traded after 2012, and 3) post-Kyoto commitments for Russia and the Ukraine.

4. Coming to a realistic CER market potential

The estimates in Chapter 3 represent the technical and economic potential for GHG reduction in non-Annex I countries, Russia and Ukraine, which can be regarded as an upper limit to the potential for CDM and JI projects. This chapter focuses on estimating a more realistic market potential for CDM projects.

4.1 Approach

The results described in Chapter 3 present the technical abatement potential and the associated cost. To what extent this potential can be realised by the CDM depends on a number of factors, including:

- Eligibility of the technology under the Flexible Mechanisms.
- Application of the additionality criterion.
- Existence and scope of approved methodologies.
- Success of Programmatic CDM.
- Investment climate and institutional environment in the host countries.
- Policy and technology developments in host counties.
- Economic attractiveness to develop the technology (other than abatement cost): CER revenue compared to total investment and average scale of technology.
- Performance of the technology (issuance success).
- Technical barriers.
- Other barriers related to social adoption of technologies.

To take these barriers into account we will look at each technology in the MACs and make an assessment to what extent its potential could be realised under the CDM. Four technical and policy scenarios reflecting the above-mentioned factors are developed in order to indicate the likely range of the market potential, while still taking into account the inherent uncertainty in any such assessment. These scenarios should be seen as an attempt to give a semi-quantitative analysis of what the impact of several uncertainties on the potential for CDM project may be, rather than an exhaustive study into the market potential.

Transaction costs are taken into account in the MACs in Figure 3.2 by calculating premiums that are added to the abatement cost, which are relate to 1) the CDM project cycle, and 2) investment risk in different non-Annex I countries. In addition to the transaction costs there could be non-economic barriers that cannot readily be expressed in the transaction cost (see above). Therefore the scenarios were developed, and these should be regarded as an attempt to give a semi-quantitative illustration of what the impact of several uncertainties on the abatement potential for CDM projects may be. In the scenarios only the abatement *potential* of the options has been varied, not the cost. The following sections explain in more detail the approached used.

4.1.1 Eligibility

As indicated in Chapter 3 several technologies are not eligible under the CDM and are under discussion. Other technologies are eligible only to a certain extent. Table 4.1 summarises our assumptions regarding eligibility for selected technologies, where the figures should be regarded as multiplication factors for the abatement potential. Project types not listed are considered eligible for 100%.

Table 4.1 *Eligibility assumptions for CDM technologies*

Technology	Low estimate	High estimate	Explanation
Avoided deforestation	0	1	Under discussion (no official process under the UNFCCC yet)
CCS	0	1	UNFCCC process ongoing
Clean coal technologies	0.15	0.15	Approved baseline methodology (UNFCCC, 2007) determines that registered CDM projects need to be included in the baseline (sunset clause)
HFC-23 destruction from HCFC-22 plants	0.8	1	Low estimate refers to the potential if new plants are not eligible for CERs, which is being discussed within the UNFCCC.

4.1.2 Additionality

Proving additionality of a proposed CDM project, i.e. that the project would not have been implemented in the absence of the CDM, is in many cases not straightforward. For many non-CO_2 projects it is clear that only CDM provides the incentive to implement the project, as there are no other revenues than the CERs (e.g. N_2O destruction activities). For most CO_2 projects however there are also revenues due to reduced cost of energy (energy efficiency projects) or revenues from the sale of electricity (renewable energy projects or fossil fuel switch in power generation). Project proponents can use two options given in the additionality tool as developed by the CDM Executive Board (UNFCCC, 2006): investment analysis or barrier analysis. Both routes provide some room for gaming and are to a certain extent subjective for these types of projects; assumptions on prices and economic attractiveness are not always straightforward, and exactly which non-financial barriers a technology faces is hard to verify in each specific case (although it is clear that in general non-financial barriers prevent uptake of seemingly economically attractive technology).

Michaelowa (2007b) analysed 19 registered Indian CDM projects related to energy efficiency and renewable energy and raised doubts about the additionality of five of them, and concluded that two other registered projects were not additional. In the Final report of the 4th meeting on the ECCP working group on emission trading (ECCP, 2007), it was argued that up to 30-50% of CDM should not be viewed as additional, of which renewable energy projects take a large share. In Haites (2004) a CER supply tool developed by Trexler and Associates is discussed, which applies different additionality stringency criteria (based on qualitative assessment). If the medium stringent approach (Additionality 3 scenario) is applied the CDM potential is more than double than that of the most stringent approach (Additionality 5). The application of additionality criteria is clearly a crucial issue for the CDM market potential.

Table 4.2 *Additionality scenario (correction factors) for selected technologies*

Technology	Low estimate	High estimate	Explanation
Avoided deforestation	0	1	See Section 3.5
Renewable electricity	0.5	1	See ECCP (2007)
Cement blending	0	1	Projects are rejected by the CDM EB (CDM EB, 2007b), and additionality tool may be reconsidered
Waste fuel utilisation	0	1	

Table 4.2 gives our assumptions regarding the stringency of additionality application, where the low estimate show the share of technologies that pass the test in the most stringent case and the high estimate in the least stringent case.

For all other technologies we have assumed that additionality is less problematic. For energy efficiency technologies - though additionality is debated for many projects - no difference is made, because the arguments used in the barrier analysis of the additionality test are covered below in other technology barriers.

4.1.3 Investment climate

Attractiveness to invest and the institutional CDM environment (including pro-activeness of the DNA and conducive approval procedures) in host countries are important issues for CDM project developers, and much quoted to explain the low share of projects in African countries.

In the context of the TETRIS project, a composite indicator for attractiveness of host countries has been developed (Oleschak & Springer, 2006). This so-called indicator of the risks of investing in GHG mitigation projects consists of three components:

1. Institutional environment for JI and CDM activities
2. Regulatory environment
3. Economic environment.

For each of these three aspects country indicators are estimated, weighted and aggregated into the composite indicator. Non-Annex I countries are then aggregated into three groups:

- On the top: India, Mexico, Brazil and China: They are on the top mainly because of their institutional excellence.
- Next there are countries such as Morocco, South Africa, Costa Rica, Argentina, Colombia and Bolivia: they have put some effort into institutional building.
- Further down there are countries such as Uganda, El Salvador, Nicaragua, Viet Nam, Peru, Guatemala, Honduras, Ecuador and Indonesia: below average investment climate but good institutions concerning CDM projects.

The risk indicator is then translated into additional cost for the CDM project developer, i.e. the abatement cost for technologies in these countries increased. In the TETRIS project the MAC have been adjusted upwards by applying the risk factor to the relevant country, which varies for 1.8% for India and China to 16% for African countries (Böhringer et al, 2006). This approach is be incorporated in the methodology for the current study also, however the overall impact on the MACs is limited.

4.1.4 Social technology adoption rate

The existence of a large no-regret abatement potential (both in Annex I and non-Annex I countries) suggests that there are non-financial barriers that prevent uptake of these technologies. Particularly energy efficiency technologies are faced with these barriers, which include:

- Split incentives (cost incurred by building owner, benefit by tenant).
- Information barriers (unfamiliarity with the option).
- Preferences that cannot be captured in economic cost (comfort rather than cost).
- Turnover of capital (the investment into a more efficient technology is only economical when investment in new equipment or buildings is done).
- More risky technology (less experience with operating a gasification plant compared to conventional coal combustion).
- Capital constraints.
- Higher discount rates.

As mentioned before, it is not possible to adequately capture these barriers in financial terms. Therefore we aim to include these barriers into the abatement potential by incorporating it into the scenarios (see Section 4.1.8). For all energy efficiency technologies in the industry, power, transport and buildings sector we apply a factor 0.5 to the technical potential in the low estimate and 1 in the high estimate. As the estimate for the technical potential for energy efficiency is 1.7 $GtCO_2$ in 2020, this has a strong impact on the result for the market potential.

It should be noted that the non-financial barriers are very much related to the additionality criterion. We assume however, that if these projects are able to overcome these barriers, they are also additional; therefore no correction is made for additionality of energy efficiency projects.

For avoided deforestation the scenarios elaborated in Section 3.5.1 are used. The maximum realisable potential is assumed to be 25% of the technical potential in the Rainforest Coalition, while the minimum is assumed to be 5% of the technical potential.

4.1.5 Host country policy and technology trends

Estimates of the technical potential of technology options are in general optimistic about the implementation opportunities. Whether this is likely to happen in practice depends on a conducive policy environment. For example if a government is opposed to hydropower, its potential is not going to be realised.

On the other hand, mandatory policy that is strictly implemented may render potential CDM projects non-additional: when a government has a strong policy on the utilisation of biofuel (e.g. mandatory blending of biodiesel for oil companies) which is enforced also, then biofuel projects in that country are only additional if they increase the biodiesel above the mandatory value. In the current study this ‘perverse incentive of the CDM’ is ignored, as it can be observed from the current CDM pipeline that many renewable energy projects are developed and registered in countries with policy targets for renewables. In these cases the PDDs argue that the ‘mandatory’ policy is not or badly implemented in practice and the CDM project aids in realising the policy goal.

In order to give a ‘reality check’ to the technical potential we list renewable energy goals for a limited number of important CDM host countries (see Table 4.3), taken from the regional reviews related to the current study. As part of the regional reviews, information on relevant regional policy developments and goals was requested to be supplied by expert reviewers in China, India, Senegal and Brazil. The regional reviews included useful information for Asian countries and Brazil, which was taken into account in the technical potential data, and mentioned in Table 4.3.

Table 4.3 *Estimates of additional CO_2 reduction by additional policies under consideration.*

Country	Technology	Policy goal	Year	Likely GHG reduction ($MtCO_2$/yr)	Source
China	Biomass and waste	80 TWh	2020	64	Review by CREIA (2007)
	Wind	30 GW	2020	60	
	Small hydro	25 GW	2020	120	
	Biofuels	10 Mt petroleum equivalent	2020	30	
	Renewable electricity	16% (10% in 2010)	2020	unknown	
India	Renewable electricity	10% of total	2012	unknown	Regional review IT Power India
	Hydro	7 TWh	2015	6	IEA 2006
Brazil	Biofuel (production + consumption)	48 Mm^3 (24 in 2010)	2020	ca. 70	Regional review by Centro Clima

Note: Renewable electricity assumed to replace fossil electricity with an emission factor of 0.8 tCO_2/MWh.

4.1.6 CDM policy developments: Programme of Activities

Successful development of programmatic CDM (officially called CDM Programme of Activities, PoA) would increase opportunities for certain technologies (see Chapter 5 for a detailed discussion of programmatic CDM) to be developed under the CDM. Our assumptions (i.e. correction factors) for the impact on the market potential compared to the technical potential are shown below. A distinction is made between the industrial energy efficiency projects, biofuel and agricultural methane projects - which are relatively large and are already implemented to some extent under the current CDM - on the one hand, and the smaller and more intricate projects (building energy efficiency and transport) on the other hand. As transaction cost are already considered to be low (less than 1 €/tCO_2-eq) further reduction by PoA is not considered significant and therefore not taken into account. We feel the impact of PoA can better be represented by increased uptake of technologies in the potential figures.

Table 4.4 *Assumptions (correction factors) relevant to programmatic CDM technologies*

Technology	Low estimate	High estimate
EE buildings	0.2	0.8
EE industry/power	0.5	1
Biofuel consumption	0.5	1
Transportation	0.2	0.8
CH_4 agriculture	0.5	1

4.1.7 Other barriers not taken into account

The barriers listed in the previous sections are considered in the scenario approach (explained below). Factors not taken into account include:

- Use of approved baseline and monitoring methodologies. We assume that approved baseline methodologies (AM) exist with sufficient scope to be applied to the technologies in the MACs. For CCS, biofuels, LULUCF and the entire transport sector no or few AMs exist, however the CDM Executive Board is moving towards more methodologies in these sectors as well. It is therefore very difficult to say to what extent this will continue to be a barrier.
- Performance of technology (see also Section 2.1); although currently registered projects have generated significantly less CERs than projected in the PDDs, we consider this an issue not related to potential of the technologies (project developers have an incentive to be more optimistic about their particular project in order to attract investors). A correction for the

striking underperformance of landfill gas projects (performance of ca. 30%) to the abatement potential may be considered.
- Scale of the project: large projects are in general more attractive for project developers, particularly if the upfront investment can be covered by (projected) CER revenues. However, transaction cost for different types of technologies and typical project sizes are already in the TETRIS database.

4.1.8 Overview of approach

The barriers discussed in 4.1.1 to 4.1.6 are incorporated in scenarios that aim to gain more insight in the market potential for CDM projects in 2020. The scenarios are developed along two axes:
- Technology axis, where going from the 'pessimistic' end to the 'optimistic' end implies more technologies get implemented as non-financial barriers play a smaller role.
- CDM related policy environment, where along the axis more technologies are eligible, proving additionality is not problematic and programmatic CDM is a success.

The scenarios are shown schematically in Figure 4.1.

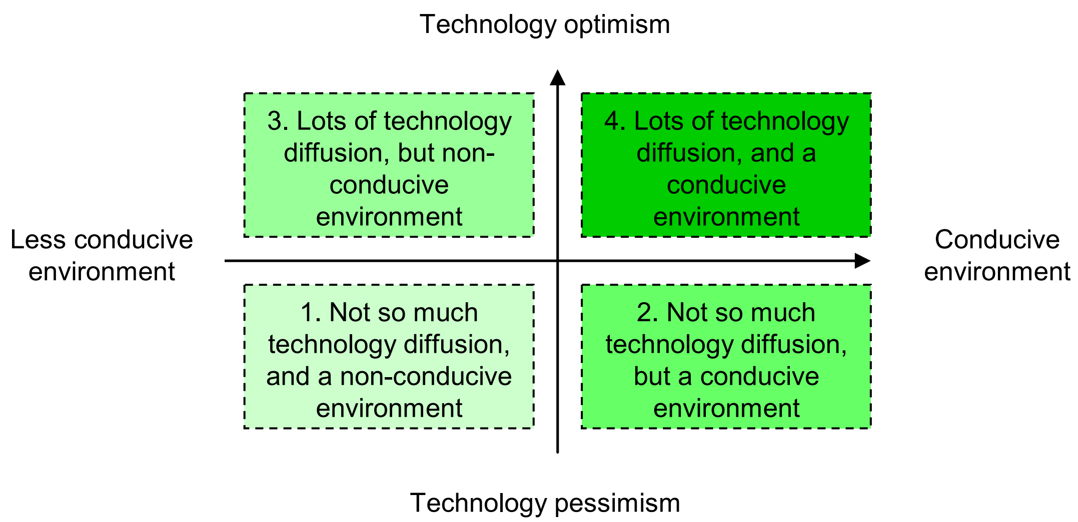

Figure 4.1 *Scenarios for estimating the CDM market potential*

- Scenario 1: Low eligibility, strict additionality, unsuccessful PoA, and large barriers for energy efficiency projects.
- Scenario 2: CCS and other technologies are eligible and PoA is successful, but large barriers for energy efficiency.
- Scenario 3: Energy efficiency projects face less barriers, but low eligibility and unsuccessful PoA.
- Scenario 4: High eligibility, projects easily pass the additionality test, successful PoA and fewer barriers for energy efficiency.

4.2 Results

Applying the approach explained in 4.1 downsizes the technical GHG abatement potential into possible market potentials and costs as shown by the MACs in Figure 4.2. We can observe that the assumptions on technology adoption and CDM policy developments have a strong effect on the potential. Eligibility of technologies and rules for additionality may play an important role, which is confirmed by other studies (Haites, 2004; Michaelowa, 2007b). The most pessimistic scenario indicates a potential of 1.6 $GtCO_2$-eq/yr up to € 20/tCO_2-eq while the most optimistic scenario yields 3.2 $GtCO_2$-eq/yr at the same cost level.

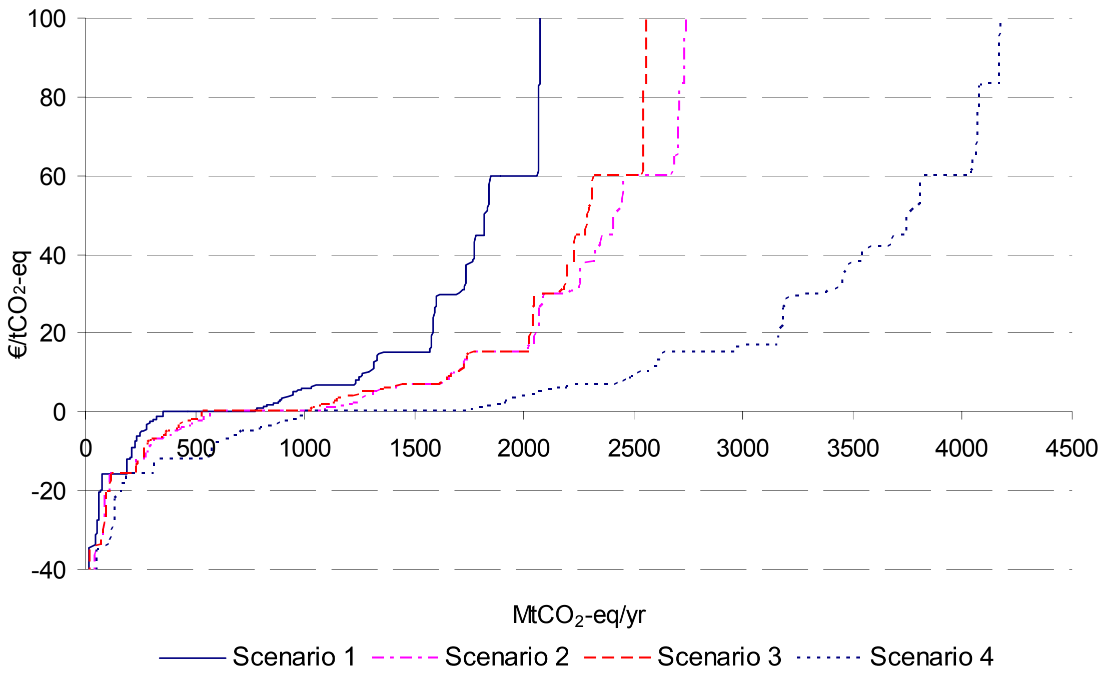

Figure 4.2 *CDM market potential for 2020 according to four scenarios*

It can be observed that the abovementioned uncertainties may have a significant impact on the market potential for CDM projects, which lies between 1.6 and 3.2 $GtCO_2$-eq/yr in 2020 for the most pessimistic and optimistic scenario respectively. The difference can be explained by the impact of non-financial barriers on energy efficiency (which represent 1.6 Gt/yr or 38% of the technical potential), and its related rules on additionality in the barrier analysis. Strictness in the application of the additionality criterion is expected to impact renewable energy, cement blending, avoided deforestation and waste fuel utilisation projects. In addition the eligibility of avoided deforestation has a significant impact: in Scenario 4, a market potential of 350 $MtCO_2$/yr is included.

4.3 Discussion of results

The technical potential of more than 4.3 $GtCO_2$-eq/yr in 2020 is very large and likely to outstrip demand for credits in several scenarios (even ignoring the JI potential in Russia and the Ukraine and possible IET). However GHG reduction activities in general and CDM projects in particular face a number of barriers that cannot be expressed in the abatement cost. Therefore an attempt to assess the market potential, i.e. including non-financial barriers, can be justified.

A set of uncertainties needs to be addressed in any approach thereto which also inevitably includes a degree of subjectivity. In our approach the most important barriers are taken into account and an assessment of the impact on the market potential is given for different technologies. Thereby some additional insight is gained into the likely range of the market potential for CDM projects following different possible courses of development of the CDM market.

This market potential could be significantly smaller than the technical potential. The methodology could be refined and assumptions would benefit from more expert judgement. The lower estimates of the market potential in 2020 are in the range of possible demand scenarios.

A comparison with other studies could be useful, however bottom up studies on the abatement potential for 2020 in non-Annex I countries have not been found. Most reports are results of top-down economic modelling, involving a lower degree of technical detail than bottom up assessments. A report on behalf of the UNFCCC (Haites and Smith, 2007) indicates a potential for CO_2 reduction (for non-CO_2 options only a small N_2O potential is mentioned) of 7.7 $GtCO_2$-eq/yr in 2030, of which LULUCF and CCS take up 4.5 Gt/yr. This is considered to be in line with our assessment, as CCS is important mostly after 2020.

Cames et al (2007) conclude from economic modelling that there is a potential for CO_2 reduction in 2020 of 5.7 $GtCO_2$ and ca. 1 Gt for non-CO_2 sources in non-Annex I countries. The results of the first study are comparable to the technical abatement potential identified in Chapter 3. The figure of 5.7 Gt/yr in 2020 for CO_2 only in Cames et al (2007) is significantly higher than the potential we identified in our bottom up study.

Vattenfall (2007) includes a comprehensive peer-reviewed assessment of the global potential and cost for GHG reduction in 2030, of which 16 $GtCO_2$-eq/yr exists in non-Annex I countries up to 40 €/tCO_2-eq. Results by sector:

- Industry: 3 Gt.
- Power 2.8 Gt (which includes nuclear, and a large role for CCS, excluding power demand reduction).
- Transport: 1.4 Gt.
- Buildings: 1.6 Gt (estimated to be ca. 0.8 Gt in 2020, including power demand reduction).
- LULUCF 3.3 $GtCO_2$ in 2030. This figure is higher than our findings for 2020, but this can reasonably be explained by the difference in cut-off year.

The results appear to indicate a larger potential for 2020 than we have calculated for most sectors, notably the transport and industry sector.

In the Fourth Assessment Report of the IPCC (2007) the GHG reduction potential up to 20 \$/tCO_2-eq in non-OECD countries is estimated to be approximately 7 $GtCO_2$-eq/yr in 2030, of which the building sector take about 3 Gt/yr. The total potential (up to 100 \$/tCO_2-eq) is ca. 12 $GtCO_2$-eq/yr.

The differences with the above-mentioned studies may be explained by differences in approach: in the TETRIS study - which is the basis for the current study - only the abatement potential that is actually mentioned in detailed country abatement studies is taken into account. Those studies are likely to be incomplete: if no reliable data were found for options these were not taken into account. Therefore e.g. the potential for GHG reduction by biomass combustion is likely to be underestimated. Other options might have been underestimated also. To some extent we have provided additional options that were not covered by the country studies (LULUCF, CCS, non-CO_2 options), however incompleteness can be a source of underestimation.

5. New developments in the CDM

This chapter pays special attention to the recent development of programmatic CDM, including its potential impact on CER supply, and possible future directions regarding sectoral crediting mechanisms.

5.1 Programmatic CDM

The CDM has proved to be an effective market tool for capturing low-cost emission reduction options and thus helping Annex-1 countries in meeting their obligations under the Kyoto protocol in a cost-efficient manner. However, it has been less successful in achieving its second objective of realising the development dividend in the host developing countries. One of the major reasons for this is that the predominantly single-project approach does not have the capacity to bring about the larger structural changes needed for a transition towards a more sustainable energy production and use. Although, from the micro point of view, it is the small-scale projects that yield the highest sustainable development benefits, and several steps to facilitate their implementation have already been taken, it will take larger-scale changes to push for the decarbonisation of developing economies.

Against this background, programmatic CDM (pCDM) actually evolved from the idea of 'sectoral' or 'policy based' CDM that would encourage developing countries to implement regional, sectoral, sub-sectoral and cross-sectoral projects, which would be the results of specific sustainable development policies, measuring the attained reductions, and selling those on the international emission reductions market (Samaniego and Figueres, 2002). The concept of sectoral CDM was subsequently expanded to include both public and private measures (Bodansky et al, 2004) and the term 'programmatic crediting mechanism' has been introduced.

A CDM program of activities (PoA) is considered a 'voluntary coordinated action by a private or public entity which coordinates and implements any policy/measure or state goal (i.e., incentive schemes, voluntary programs), which leads to GHG emission reductions or increases net GHG removal by sinks that are additional to any that would occur in the absence of the PoA via an unlimited number of CDM program activities (CPA) (CDM EB 32, 2007, Annex 38). Elaborated further, the core characteristics of programmatic CDM project activities are:

- They occur as the result of a deliberate program, that is either a public sector measure (voluntary or mandatory) or a private sector initiative.
- The program results in a multitude of dispersed actions that are induced by the program and would not occur but for the enactment of the program.
- The GHG reduction actions do not necessarily occur at the same time.
- The type, the size and the timing of the emission reducing actions induced by the program may not be known at the time of project registration. However, the types and sizes of the expected actions have to be identifiable ex ante, attributable to the program and verifiable ex post.
- While programmatic project activities can be implemented by one or more entities, they have only one enacting agent, responsible for providing the incentives or obligations to stimulate the individual actions under the program. The enacting agent must be one of the project participants, and can be either a private or a public entity.
- The programme is the project: the mitigation actions that are implemented under the programme do not constitute separate CDM projects, but must be measured and monitored according to approved methodologies to ascertain their contribution to the emission reductions achieved by the programme.

- The programmatic project activity is submitted to validation and registration through one single Project Design Document (Figueres, 2005).

Although there are no pCDM projects registered as of yet, there is a number of projects with programmatic-like characteristics already in the CDM pipeline. The figure below presents some practical examples of those, including a program to implement energy efficiency standards, a demand-side management program and a few renewable energy projects.

The EB has recently prepared the PDD design for CDM PoA and revised a number of approved small scale-methodologies to allow for their application under a PoA. Out of the 2037 projects in the CDM pipeline in June 2007, there were ten projects with programmatic CDM characteristics that have already been registered and eleven more at validation stage. Next year, China is to host a greenhouse gas reduction programme that could generate carbon credits through a policy of installing energy efficient light bulbs, which would be the first proper example of pCDM (Point Carbon, Oct 2007). The majority of the pCDM-like projects are SSC project, fourteen of which are renewable energy projects (mainly solar and biogas) and five are EE improvement projects.

Figueres (2005) assessed programmatic project activities against the requirements for CDM project activities and concludes that all of them can be met without significant alterations of standard modalities. Overall, there are not many methodological differences between programmatic and single-site CDM. Recently, the CDM EB revised a number of approved small scale methodologies to allow for their application under a PoA, thus paving the way for increased implementation of programmatic CDM. A large part of the revised methodologies do not incorporate significant change, most modifications were made to monitoring requirements and accounting for leakage.

One point worth mentioning is the additionality of program activities based on mandatory government policies. This question was resolved in the EB meeting 32 in June 2007 when the EB decided that PoAs based on mandatory policies can be additional as long as 1) they can prove that rules would not be systematically enforced and that non-compliance with those requirements is widespread in a particular country or region unless the proposed PoA is implemented and 2) in the case that regulations are being enforced, programs would need to show that they “increase the enforcement beyond the mandatory level required” (CDM EB 32 Annex 38).

5.1.1 Sectors predicted to benefit from programmatic CDM

Several studies cite programmatic CDM as a good opportunity for underrepresented GHG abatement options. Figueres (2005) sees it as a potential catalyst for energy efficiency, fossil fuel switching and the use of renewable energies, especially in private households, small enterprises and transportation, where technology improvements do not usually take place on their own but typically require the impetus of a deliberate program. Similarly, Ellis (2006) sees significant un-tapped potential in high emitting sectors such as energy use and transport whose attractiveness can be increased with clear guidelines and methodologies for CDM activities under a PoA.

Potential emission reductions in other sectors can also be significant, e.g. the potential from increased cement blending is estimated to range between 110-370 Mt CO_2-eq/yr[13], and several different energy efficiency processes in iron and steel manufacture could lead to emission reductions of similar magnitude (IPCC 2001).

[13] The additionality of cement blending under the CDM could be questionable, as argued in Chapter 4.

5.1.2 Assessing programmatic CDM potential against the MAC curves

The quantification of the abatement potential that pCDM can facilitate and thereby provide additional supply of CERs will be based on the updated TETRIS database of GHG abatement potential for non-Annex 1 countries. Various approaches could be followed to achieve this, which differ in the level of detail of realistically achievable abatement within the timeframe of this study. Starting with the most restrictive, the additional supply of CERs from pCDM can be calculated by summing the abatement potential of the pCDM project types for which approved methodologies are already in place (CDM EB 33 Annex 22-40). This approach also takes existing methodologies into consideration for large scale EE improvement projects that Hinostroza et al. (2007) find to be particularly relevant for pCDM as well (AM44, AM20 and AM 46) and five new proposed large-scale methodologies with the same prospect of applicability (NM 18, NM 197, NM 211, NM 205 and NM 142). Given the fact that the transport sector is likely to benefit significantly from the development of pCDM, we also included a category of 'unclassified' transport mitigation options that do not fit in any of the beforementioned categories but represent a considerable amount of abatement potential that should not remain overlooked.

The abatement potential of the pCDM was quantified by using the technology-specific potential data from the updated TETRIS database. A systematic search of the various mitigation options covered by the abovementioned methodologies was performed within the database and potentials of technology options falling into the respective categories (as defined by the methodologies under consideration) were summed up. The results presented in Table 5.1 are summarised for broader project types, a more detailed breakdown of methodologies and technology options considered can be found in Appendix D.

Table 5.1 *Abatement potential of project types likely to benefit from pCDM developments*

Project type	Abatement potential in 2020 ($MtCO_2$-eq/yr)
Thermal energy and renewable electricity	238.4
Supply-side energy efficiency	231.1
Demand-side energy efficiency	449.2
Switching fossil fuels	57.5
Transport	614.3
Total	1590.5

Although covering a very large spectrum of country-technology abatement options, the database does not include examples of all the abatement possibilities for which methodologies exist (those options are nevertheless listed in the annex). Most notably the methane-related abatement options studied so far seem to be incomplete, which makes for a notable shortfall given that there are already several approved methodologies for methane-mitigation options, which we were unable to quantify. The reason why no potential has been identified for avoidance of methane production or recovery in wastewater treatment is that policy approaches directly targeted at mitigating CH_4 emissions from wastewater are limited. Several factors contribute to difficulties in developing MACs for wastewater abatement options, especially for smaller decentralized systems that have less control over the share of aerobic versus anaerobic decomposition and have few feasible options for capturing CH_4 (EPA, 2006). There are similar difficulties with assessing the potential of the other missing project types.

Nevertheless, we can still provide an estimate of the abatement potential that is more likely to be mobilized because of the recent developments with the pCDM. Starting with the most restrictive approach that considers only the already approved methodologies, we reach an abatement potential of approximately 1 $GtCO_2$-eq per year (in Table 5.1 this represents the first four categories of project type and a smaller part of transport projects) which extends to almost

1.6 $GtCO_2$-eq if newly proposed methodologies and other yet uncategorized but realistic potential in the transport sector are taken into consideration. We note that a clear distinction between the potential for single-project CDM and programmatic CDM cannot be made (due to the possible overlap discussed in Section 5.2), therefore a separate estimate of the *additional* potential by PoAs cannot be generated. It is claimed that pCDM will increase the likelihood of implementation of abatement technologies that together could amount to between 1 and 1.6 $GtCO_2$-eq. Many of the options assessed to likely benefit from pCDM are already present in the CDM pipeline as stand-alone projects that had to overcome the significant barriers to project implementation. The recent developments in pCDM can further facilitate the uptake of those options (see also Section 4.1.6) as well as other less represented ones. In the approach for market potential of CDM projects, Section 4.1.6, this is taken into account.

5.1.3 The issue of ex-ante calculation and ownership of CERs

Providing accurate *ex ante* estimates of the amount and CERs from multiple program activities may be a complicated task, particularly if the exact number of project activities within a program is not known up front. However, CERs are issued on the basis of an *ex post* calculation. Sometimes significant differences can occur between the *ex post* and *ex ante* calculations. At the international (i.e. EB) level there are no sanctions for large differences in *ex post* and *ex ante* calculations of emissions benefits from CDM projects (Ellis, 2006).

The potential difficulty of developing accurate *ex ante* calculations for programmatic CDM has been dealt with by allowing a CDM project activity (CPA) to be included in a registered PoA at any time during the duration of the CPA. At registration, the PoA only has to define the type of information which is to be provided for each CPA to ensure that leakage, additionality, establishment of the baseline, baseline emissions, eligibility and double counting are unambiguously defined for each CPA within the PoA. Once added, each CPA must be uniquely identified, defined and localized in an unambiguous manner including the exact start and end date of the crediting period, by providing, at the stage it is added to the registered PoA, the information required by the registered PoA (CDM EB 32 Annex 28).

Individual CPAs under a PoA can start at different times and be registered as individual projects to ensure that all emission reductions induced by the PoA earn CERs. The crediting period of individual CPAs is either a maximum of seven years, which can be renewed twice, or a maximum of ten years without the option for renewal. The entire crediting period of the whole PoA can last a maximum of 28 years (or 60 for afforestation and reforestation).

An issue that gained more attention with the introduction of programmatic CDM is that of CERs ownership. In programmatic project activities, emission reductions achieved at the level of individual CPAs must contribute to the emission reductions of the overall PoA, therefore CERs can only be claimed by project participants at the program level. With several project participants that can potentially be CERs claimants, this issue is usually resolved through an agreement among all participants that grants the right to ownership of the CERs to one participant or a group of participants.

5.2 Sectoral crediting mechanisms

5.2.1 Definitions

Suggestions on extending the scope of the CDM from a project-by-project level to a sector-wide level and discussions on increasing the own contribution to emission reduction by more advanced developing countries developed into proposals on the Sectoral Crediting Mechanism (SCM). Sectoral crediting is seen as a mechanism to *credit* reductions at the sector level: baseline emission levels/rates and certified emissions would be defined for a range of sources defined as a sector. The difference between the baseline emission levels and emissions from the sector would be credited through an international procedure. Thus, national governments or specific authorities would be designated to allocate credits to individual sources where appropriate (Baron and Ellis, 2006).

Two alternative suggestions developed with regard to sectoral crediting - one that regards it as a way to reform the CDM and enhance the existing CDM framework by expanding it to a sectoral level and the other that regards it as a mechanism complementary to the CDM and outside its boundaries. Although the latter approach has been receiving increasing support in literature, the two ways of understanding sectoral crediting do not actually differentiate much in terms of the mechanism's design and operational issues.

5.2.2 Options for sectoral approaches

Sectoral approaches could take several forms. Bradley and Baron (2007) group them in two broad and four more elaborated categories:

I. Some form of *international agreement by an industry* to achieve certain goals related to global GHG emissions, with or without government endorsement. Within this category, two more detailed proposals include:
   - *Transnational quantitative sectoral approaches*: those would best fit the possibilities of highly-concentrated sectors, such as the aluminum industry. They can be voluntary or mandatory, in which case some kind of agreement would be stipulated presumably between the global industry and the UNFCCC. They can lead to fixed targets or indexed targets - an option which global industry usually prefers. These approaches could also result in the adoption of emission standards or benchmarks.
   - *Technology-oriented approaches*: those would focus directly on the promotion of the development and dissemination of more energy efficient and cleaner technologies. As opposed to transnational quantitative approaches, technology oriented approaches might be based on knowledge sharing and coordination, and extend to the sharing of R&D efforts[14]. Initiatives from an industry sector can be 'recognised' by the government in what is often named 'voluntary agreements'.

II. *A developing country's initiative limited to a sector, recognised by the international community* (e.g. UNFCCC Parties). Two options are envisioned towards that goal:
   - Firstly, the possibility to extend *GHG crediting to a sector (as a form of sectoral CDM or 'no-lose sectoral targets')*; this approach would commit a country to achieve an emissions goal limited to a sector. This commitment to the international community would presumably open the possibility for emission trading if the sector goes beyond the set objectives. This would provide the main incentive for DC participation in such a system.
   - Secondly, the *introduction of sustainable development policies and measures (SD-PAMs)* that seek to promote the sustainability of economic development and, incidentally, contribute to lower GHG emissions. The international agreement mentioned above could of course lead to the implementation of sectoral crediting or SD-PAMs.

In one of the country-based (II) forms, sectoral crediting would push for voluntary emission reduction targets in non-Annex 1 countries and reward the sectors/subsectors that exceeded

[14] Examples include The IEA Implementing Agreements, the Generation IV Nuclear Partnership, the International Partnership for the Hydrogen Economy, the Carbon Sequestration Leadership Forum. The Asia Pacific Partnership hosts a series of technology-oriented discussions, though they focus on the deployment of current technologies, not on R&D. In the private sector, the International Iron and Steel Institute has introduced a CO_2 breakthrough programme, which explores radical innovations to allow steel making with much lower levels of CO_2 emissions.

them by making them eligible for emission reduction credits (ERCs) which could be sold to developed countries. This approach would mean that all GHG emissions generating facilities in a given sector in a participating developing country would be included in the system, unlike in the CDM where only a limited number of facilities in a sector participate. Reductions achieved beyond the country's sectoral pledge would be considered automatically 'additional' and available for sale, thereby eliminating host countries uncertainties about emissions additionality (Schmidt et al, 2005). More details on this approach are provided in Section 5.2.5, which explains how credits under a country-based sectoral crediting approach would be generated.

5.2.3 International agreement vs country participation

There are several advantages to a country-based SCM rather than an international industry-wide SCM. Most importantly, countries have much clearer legal authority to ensure that firms operating within their borders comply with program requirements, while establishing a new legal institution to enforce sector-wide targets at the international level, would likely require lengthy and contentious international negotiations (Schmidt and Helme, 2005). Within the context of addressing concerns about competition, two contrasting arguments favor each of the approaches. In principle, an international industry-wide agreement addresses concerns about leakage (moving of business from covered to not-covered countries) and competitiveness (equal treatment of all companies operating within a sector). On the other hand, there is often little homogeneity within a sector in one country, and even less among international sectors. A single international baseline could penalise the least developed sectors from individual countries in cases where it was set too high for them to reach a reduction level beyond it (and when financial reward starts), thereby decreasing its attractiveness for investors.

The sectoral approach aims to include all major developing countries, but special emphasis would be placed on encouraging the participation of the countries responsible for the majority of the electricity and key industrial sectors' operations and emissions. Other countries would be free to join the program, but the focus at first would be on those responsible for the majority of the emissions in the sector. Fortunately, a relatively small number of nations account for a sizeable share of the developing country fraction of GHG emissions in most sectors - covering 80-90% of non-Annex I emissions for the electricity and major industrial sectors requires the participation of ten or fewer countries in each sector and only 20 developing countries overall (Schmidt et al, 2006).

Table 5.2 *Top ten developing country GHG emitters for the electricity and major industrial sectors*

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

Source: Schmidt et al., 2006.

5.2.4 Sector participation in SCM

Regardless of the option for crediting chosen to promote sector-wide crediting (international industry or country-based), one of the main issues is to determine which sectors to include given the influence this has on the structure of such a program. Sectors that will allow for the biggest realization of emission reductions under a sectoral approach are those characterised by: (1) a relatively small number of entities; (2) comparatively easy data collection; (3) fairly homogenous products (except in the cases of oil refining and pulp & paper); and (4) participation in international trade (except in the case of electricity). An additional factor driving the choice of sectors is a desire to include all sectors which directly compete with one another to minimise the likelihood that the program may provide indirect incentives for a non-covered competitive product[15] (Schmidt, 2005).

Considering the above Helme (2005) identified the following sectors as particularly promising under sectoral crediting: electricity, cement, steel, oil refining, pulp/paper, metals, etc. The inclusion of the top 10 largest GHG emitting developing countries in each sector would ensure coverage of 80-90% of developing country GHG emissions in each of the selected sectors. Furthermore, these sectors combined produce approximately 33% of non-Annex I and 15% of global non-LUCF GHG emissions, which already in the year 2000 amounted to some 5 $GtCO_2eq$ (Schmidt et al, 2006).

These estimates do not even include the transportation sector, also often cited as eligible to participate in a sector-based credit generation mechanism. Examples of transportation sectoral approach options include greenhouse gas vehicle standards, alternative fuel standards and upstream regulation of oil refineries (Schmidt and Helme, 2005).

Since there is no universally accepted definition of a sector, defining the boundaries of a sectoral crediting approach is likely to be a challenging task. Schmidt et al (2006) suggest using bottom-up criteria (e.g., combustion facilities above 20 MW) to define each sector; an alternative could be to use the definitions from the European Emissions Trading System as a starting point for the establishment of sector boundaries.

5.2.5 Emission reductions under a sectoral crediting mechanism

In the proposal on SCM elaborated by the Center for Clean Air Policy (Schmidt et al, 2006), the basic mechanism of the sectoral approach in the form of a country-commitment on a sectoral level is designed as follows. Through a negotiation process, key developing countries would pledge to achieve a voluntary sector 'no lose' GHG intensity target (e.g., GHG / ton of steel) in the electricity and key industry sectors. Any emissions reductions achieved beyond the 'voluntary pledge' would be eligible for sale as emissions reductions credits to developed countries. Emissions reductions to meet the country's pledge would be permanently 'retired from the atmosphere' and thus would not be eligible for sale (see Figure 5.1). However, failure to meet the 'voluntary pledge' level would not involve any penalties or any requirement to purchase emissions reduction credits from other countries.

The 'no-lose' targets would be established through a three-step process:

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

[15] For example, if the iron and steel sector is subject to an emissions intensity target, while aluminum production is not, this could induce the substitution of aluminum for steel in applications for which either material is an option.

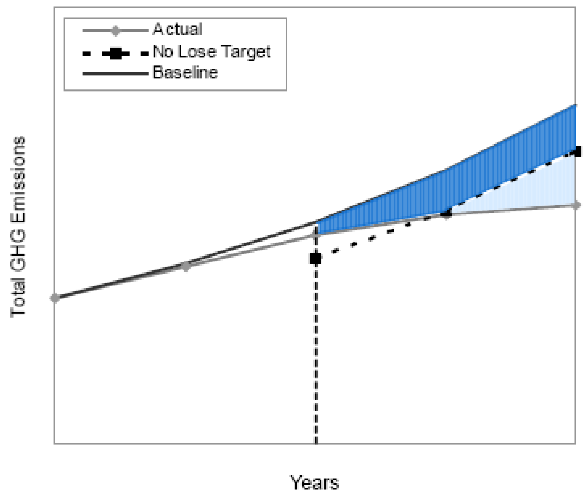

Figure 5.1 *GHG emissions 'permanently retired for the atmosphere' and emissions reductions available for sale when exceeding the 'no-lose' target*
Source: Schmidt et al, 2006.

The bold solid line represents the baseline (or business as usual) scenario, and the lighter solid line shows what actually occurs within the sector. The dotted lines show the emissions intensity target and the GHG emissions if this target is met. The vertical dashed line designates the onset of the compliance period. The shaded areas represent the emissions that are 'permanently retired for the atmosphere' (darker shaded area) and the excess emissions available for sale (lighter shaded area).

The simplest way to accurately determine the number of ERCs generated from a given sector is to perform an *ex-post* calculation, when both the actual emissions rate and production levels are known. The same proposal suggest for the sectoral approach to be designed in a manner that generates credits *ex-post*, every two years during the compliance period. This enables entities (e.g., countries or companies) to participate in carbon-market trading during the same compliance period in which the emissions reductions occur. It also avoids enforcement problems that can occur in *ex-ante* systems when countries are over-allocated ERCs (Schmidt et al., 2006).

Naturally there is no reason why the procedure described above would not be applicable to international industry-based sectoral agreements, however this would preclude the setting of one single target or standard to be used across the whole industry at a global level. National associations of industries aiming at reducing their emissions could lead the effort to develop such country-specific baselines for their sector.

5.2.6 CERs supply potential from SCM

Based on IEA (2004) calculations of emission reductions that would result from implementation of policies currently under consideration, Baron and Ellis (2006) predict that just the power sector of developing countries could generate around two billion credits per year in 2030 - provided all policies involved are deemed additional by the authority governing the mechanism. This compares to less than 40 million credits per year in 2010, also in the power sector, but generated by CDM projects (Ellis and Levina, 2005).

Based on the world sectoral GHG emissions for the year 2000, Schmidt et al (2006) compiled a list, which are presented in Table 5.2. By combining the information on the biggest ten emitters among developing countries per sector with the abatement potentials identified for the same sectors and countries from our database (see Chapter 3), we can estimate the total abatement potential that might be realised by an effective SCM. After summing up the country-technology options for the countries and sectors listed as the biggest polluters, we arrive at a figure of 1.1 $GtCO_2$-eq/yr for the year 2020, which is substantially lower then predicted by Baron and Ellis as well as the technical potential for the sectors proposed above (as identified in section 5.2.4), which already 2000 amounted to almost 5 $GtCO_2$-eq/yr. However, those larger estimates are based on emission levels only and do not take into consideration economically feasible abatement options, which is the case in our approach. Nevertheless, we can conclude that due to lack of reliable data on abatement options for many of the ten developing countries that have been identified as top GHG emitters for the electricity and major industrial sectors, our estimate represents an underestimation from the abatement potential point of view. Similar to programmatic CDM, sectoral approaches would increase opportunities for GHG reduction that now may face higher barriers under the project-based CDM. Therefore, as explained in 5.1.2 for programmatic CDM, it will be impossible to estimate the *additional* potential that could be harnessed by sectoral mechanisms, however it can be said that several gigatonnes of CO_2-eq annually of the GHG reduction potential have increased chances of being mobilised.

Another important point to take into account is that the actual availability of credits for trading will be determined by the negotiated pledged (‘no-lose’) targets that will leave less excess credits available in case they are more stringent and vice versa.

5.2.7 Limitations of the sectoral approach

Although several suggestions have been put forward on how to step up emissions crediting from the single-project CDM to sectoral crediting, a number of challenges remain to be solved. Developing sector-wide baselines could prove very difficult as there is little homogeneity in sectors. Within a sector, wide variations in greenhouse gas intensities and among facilities may mean that differentiation, and thus multiple baselines, are needed. This is not necessarily conducive to a least-cost mitigation outcome overall. Furthermore, it may be very burdensome to negotiate. One of the biggest concerns with regard to sectoral crediting is its effect on competitiveness of restricted sectors and countries, which can manifest itself in increased complexity, information asymmetry and creation of sectoral havens with lower emission reduction costs then other activities (Bradley and Baron, 2007).

As CDM experience shows, establishing a proper metric to assess genuine reduction efforts can be a technically tedious but also a contentious matter. Because of the probable diversity of situations across installations covered by such an approach and the complexity that arises from it, sector-wide crediting will require a political 'deal' to set the level of effort based on which credits would accrue (Bradley and Baron, 2007). Based on the experience from the JI, it is not unreasonable to assume this could lead to the generation of sectoral 'hot air'. Furthermore, negotiating country-specific baselines for internationally traded commodities and awarding credits for good performance without penalising underperformance may run against international trade rules, and generally be a difficult concept on which to reach international consensus (Ellis, 2006).

5.3 Overlap of CDM projects bundling, pCDM and sectoral crediting

There is certainly significant overlap between single-project CDM activities bundled together to a larger scale, a program of activities (pCDM) and sectoral crediting. As mentioned earlier, sectoral crediting is considered both outside and within the existing CDM boundaries. When the latter approach is considered, it is not clear how a distinction could be drawn between some types of SCM, and between the provisions for pCDM and bundles of large-scale CDM projects. Figure 5.5 illustrates the potential overlaps between bundled CDM projects, pCDM and SCMs. For example, if a company that dominated a sector’s emissions in a particular country decided to initiate a voluntary programme of emission reductions, and obtained credits from this, it could theoretically be done by either bundling or pCDM provisions, or potentially under a sectoral crediting mechanism. Alternatively, many (or all) projects in a particular country and sector could decide to undertake CDM activities, and present this as a single, bundled, project activity. A programme aiming to reduce emissions from different activity types within a single sector (e.g. increasing the energy efficiency of cement production and increasing cement blending) could also potentially be eligible under either the pCDM provisions, or a SCM (Baron and Ellis, 2006).

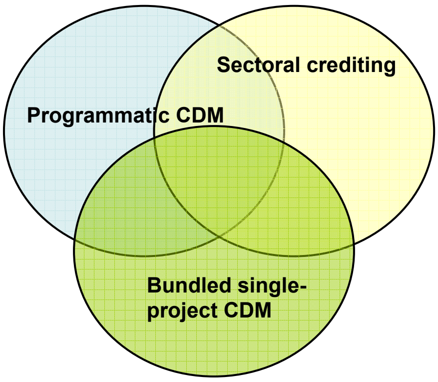

Figure 5.2 *Potential overlap between bundled CDM projects, pCDM and sectoral crediting mechanisms*

Source: adapted from Baron and Ellis (2006).

On the other hand, there are characteristics by which these approaches to organizing CDM projects can be differentiated. In the case of several similar CDM projects, the project proponents can use the option of bundling, which is appropriate in the case of a small number of medium to large units, or small units in large aggregation that belong to a limited number of owners and occur in a short period of time (Hinostroza et al., 2007). Most often, bundling brings together "several CDM project activities to form a single CDM project activity or portfolio without the loss of distinctive characteristics of each project activity" (CDM EB 21 (2007), Annex 21). The project activities included in a bundle and their sites must be indicated at the time of registration and cannot change over time. All the projects in a bundle must start at the same time and each single activity is represented by a single project participant, who is also the receiver of the achieved reductions. The purpose of bundling is merely the reduction of transaction costs for independent small project activities (Hinostroza et al., 2007).

By contrast, in the case of pCDM, the program itself is registered as the project. Typically, the program includes a multitude of GHG reduction activities that occur over a period of time and are geographically dispersed. All the exact sites may not be known ex-ante, but the type and maximum potentials are. Although there is one implementing entity, there are a large number of potential owners, a number which may not be known at the onset, who participate in the program. When a large number of units are geographically dispersed and occur over a period of time, the composition of the programmatic project activities may not be known at the time of submission (Hinostroza et al., 2007).

If sectoral crediting develops as a separate mechanism, the following relationships with the CDM could apply (Schmidt and Helme, 2005):

- New pledge process would replace CDM in the sectors and countries participating developing countries.
- For sectors not included in the proposal, CDM would proceed as in the past.
- For countries not participating in sectoral pledge:
  - Energy-intensity benchmark developed in pledge process would become minimum threshold for CDM baseline for new facilities.
  - The current CDM methodology process would continue to apply for setting baselines.

- Sectoral pledge could create a new sectoral CDM process for these countries, which could later decide to join the autonomous sectoral approach.

5.4 Summary

Many experts in the CDM field regard programmatic CDM as an opportunity for currently underrepresented sectors and project types. Due to the various dispersed activities that are required to achieve significant reductions in many GHG intensive sectors, the modalities of the predominant single-project approach were simply too complicated and expensive to implement the necessary changes required. Now that administrative procedures are being streamlined we can expect a substantial increase in similar projects that can be registered as a CDM PoA. However, more work is needed to facilitate implementation of large scale projects. Currently, there is only one such programmatic CDM-like project in the pipeline[16], although more approved methodologies could be used for potential large-scale energy efficiency programmatic CDM.

By allowing a multitude of dispersed actions to be registered as one project with a single PDD and ex-post verification of emission reductions the potential supply of CERs could be significantly increased and can reach from 1 to 1.6 billion credits with still plenty of room to revise this figure upwards. Due to overlap between stand-alone, bundled and PoA projects, it is rather difficult at this stage to determine with greater accuracy how many CERs will be supplied by which procedure. However, it is fair to say that the likelihood of this potential being realised has increased substantially with the promotion of programmatic CDM.

The sectoral crediting mechanism as an independent approach complementing the CDM rather then being integrated into it, marks a distinctly different approach to the established climate regime. Most notably, a sectoral approach envisions a clear commitment from developing countries, be it through international technology agreements or setting its own sectoral pledge. The second important difference is in the actual crediting mechanism, which assigns emission reduction credits only for reductions beyond the sectoral pledge, rather than on a project-specific basis. Note that this pledge could also be just the BAU, making it no different from a scaled-up CDM approach. On the other hand the pledge could also be wrongly set above BAU, creating new hot air. At this point it is still unknown whether developing countries would take up such commitments in international negotiations. Concerns of competitiveness of covered sectors and establishment of a proper metric to measure the performance of sectors are among the key issues.

Furthermore, without a clear signal of an adequate increase in demand, a mechanism that promotes such large abatements and requires extensive upgrading of the already established climate regime does not have a high likelihood of implementation. Sectoral crediting would require a significant amount of effort in establishing the institutional and administrative capacity to become a functional international crediting mechanism such as the CDM. At the same time, the introduction of programmatic CDM and its significant overlap with the sectoral approach reduce the incentive to invest such significant resources into the development of a new independent crediting mechanism.

16 The Bus Rapid Transit project in Colombia.

6. Carbon market scenario analysis

This chapter aims to discuss possible developments in the carbon market after 2012, in order to examine impact of climate commitments by countries on carbon trading, and the interactions between different types of credits. Point Carbon has developed three post-2012 scenarios, of which one is more or less business-as-usual (Scenario A), one is more 'optimistic' where also US and emerging economies take on GHG targets (Scenario B), the third lies between the two and sees the US participating indirectly through a domestic emissions trading scheme with a gateway to the CDM (Scenario C). Scenario A (Section 6.2) and B (Section 6.3) are analysed in a quantitative and qualitative fashion, Scenario C (Section 6.4) only qualitative.

We emphasise that the assumptions in the scenarios are the responsibility of the authors of this report and do not necessarily represent the views of the client, the Dutch Ministry of VROM- International Affairs. We furthermore emphasise that the supply assumptions in this Chapter 6 are fully separated from those as described so far in the previous chapters of this report. In Chapter 6.3.3 we will compare part of these data and results to the supply assumptions as described in this report so far.

6.1 Global demand-supply scenarios: introduction

The Global Carbon Price (GCP) model, developed by Point Carbon, is a tool that allows users to run a number of scenarios covering both key political drivers and energy market drivers. The model is designed to help users understand the potential movement of carbon prices and price sensitivities in the long-term plus the size of the market, given core underlying assumptions.

The model aims to provide a solution for the way the global emissions markets will meet any given set of international targets. It does this by establishing the size of the gap between estimated business-as-usual (BAU) emissions and target emissions reductions. It then sets out to find how that gap will be filled by considering both project-based emissions reductions and domestic emissions reductions that might come about by policies such as the introduction of an emissions trading scheme (ETS).

In order to capture these dynamics, the model is built up from the following modules:

- Global emissions module which models baseline emissions and emission reduction targets for a wide range of different countries. The module provides a base demand for carbon emissions reductions, set equal to the difference between baseline and target emissions.
- Carbon project credit module which provides a supply curve for emissions reductions credits. Here we model the supply of Certified Emission Reduction (CER) and Emission Reduction Unit (ERU) demand.
- Individual emission trading scheme (ETS) modules which provide more detailed emissions modelling of those sectors directly covered by an ETS. Here, we focus on modelling the responsiveness of emissions from covered sectors (e.g. power sectors) to the carbon price.
- Central pricing module which draws in the outputs of the other modules and uses these to determine the scenario prices - both at a global level and at an ETS level.

The CDM and JI project supply module is based on a review of existing marginal abatement cost (MAC) estimates as published by the IPCC and several private institutions. In a nutshell, the total technical potential given by the IPCC estimations for 2030 is adjusted to reflect each scenario's and time period's associated level of expected demand.

Our credit supply model is based on the following key drivers:

- Available estimates of marginal abatement costs (MACs) from publicly available sources. The key sources retained are the IPCC Fourth Assessment Report and marginal abatement cost estimates from the work recently carried out by Vattenfall (2007).
- A generic division of low, medium and high cost abatement technologies that are linked implicitly to the structure of the different MACs.
- A scenario approach to the growth in the number of projects, based on the political scenarios developed in this report.
- A scenario approach to the relative shares of the number of projects per cost category, based on the political scenarios developed in this report. In general, the more countries with targets, the greater the supply of credits assumed as demand increases are expected to be met by supply increases eventually.
- Over time, the abatement opportunities that are realised increase in all of the different technology price bands. That is, we assume that new project opportunities in all of the different price bands will occur in each of the different time periods - so that the full supply curve shifts to the right.

In a nutshell, our credit supply forecast is constructed as follows:

1. We begin with Point Carbon's projections for supply to 2012 (see also Section 2.2). Next, using public estimates of marginal abatement costs and volumes to 2030, we calibrate a base-case marginal abatement cost curve for 2030.
2. From that MAC curve, we extrapolate MAC curves for each of the preceding trading periods considered in the base case scenario by making assumptions on the growth rates of different project types. We calibrate these going backward so that supply by 2012 corresponds to Point Carbon's 2012 projections.
3. Following the same logic, we adjust the growth rates of credit supply as a function of the scenarios and time periods covered by the GCP model. Our assumptions on the different schedules of project growth per scenario are detailed below.

The result is a scenario-dependent set of MAC curves for each of the trading periods considered.

The IPCC Fourth Assessment Report (IPCC, 2007) conducted a meta-study of the results of the research on this topic available to date. In its chapter on short and medium term mitigation, the report groups the estimates of MACs conducted by third parties into two main types of modelling categories: top-down models[17] and bottom-up models[18].

The model uses a maximum price of € 100 per tonne of CO_2 equivalent. This level was chosen in part because of expectations that carbon prices would not rise above it and also because the IPCC did not assess abatement potential beyond that figure. AAUs are treated separately in the GCP and the diagrams below do not take into account the supply of AAUs. The GCP model assumes a certain percentage of surplus AAUs are sold through green investment schemes. That volume of green AAUs is effectively subtracted from total demand before the project-based credits are considered. As a result, the model considers supply from the CDM and JI project-based mechanisms only after the use of AAUs.

Some additional remarks regarding the analyses in this chapter need to be made. The Kyoto Protocol may give way to a successor protocol, the CDM may be broader in scope and is likely

[17] Studies that assess the economy-wide potential of mitigation options using consistent frameworks and aggregated information about mitigation options. They capture macroeconomic and market feedbacks.

[18] Sectoral studies based on the assessment of technological and regulatory mitigation options taking the macro economy as unchanged

to include programmes of activities, carbon capture and storage technologies and more land-use project types including avoided deforestation - even if land use project types are unlikely to generate many credits before 2012.

Similarly, green investment schemes designed to bring large volumes of AAUs to market are expected to develop in volume and sophistication, with greater acceptance of 'soft' greening quite likely. Entirely new mechanisms may be introduced, such as rewards for expenditure on research and development into low-carbon technologies. Nevertheless, the overall architecture of the market can be sketched out with some detail on certain expectations or assumptions. Following are three snapshots of the market in 2020, Scenarios A and B as described above, plus a third scenario (Scenario C) which includes a growing role for the voluntary market and its impact on the regulated market.

6.2 Scenario A: Kyoto as usual

The key premise: international negotiations enjoy partial success and the immediate post-2012 result is for incremental targets to be agreed for those existing Annex B countries that have already ratified Kyoto. In effect, the current status quo in international climate change policy is maintained.

6.2.1 Assumptions

In this scenario we assume:

- The EU continues its leadership role in pushing for both another round of targets in a second commitment period under the Kyoto Protocol, as well as a new protocol that would involve the US and major developing countries.
- The candidate to win the US presidential elections in 2009 is more climate-friendly and engages in the negotiations in good faith, with proposals for new flexible mechanisms that a new protocol that would be acceptable to Congress. However, agreement on a level of cap for the US remains difficult and takes several years to negotiate and means that a wider international agreement to take before 2020 is not achieved.
- With positive signals from the US, but progress at international level remaining slow, the parties to Annex B undertake a new round of commitments. To reflect the fact that the US is not yet ready, the existing parties move to adopt a new round of targets that are only an incremental improvement on the range displayed in the current Annex B to the Kyoto Protocol. This leaves just enough time for the Kyoto Parties to adopt the amendment and avoid a gap between trading phases, with the new caps taking effect on 1 January 2013.
- The EU takes on a combined cap of 80% of its baseline emissions in 2020, implying an 86% cap in 2015. This is in line with its 'unilateral' policy of a 20% reduction target on 1990 levels by 2020, in the absence of international agreement including China and the US.
- Japan's target is in parallel with that of the EU. It takes on a cap of 72% of its baseline emissions in 2020, implying an 83% cap in 2015.
- Canada's participation in the new round of caps under the Kyoto Protocol would be dependent on a change in government, or at least a major shift in government climate policy, perhaps prompted by a new formation in the coalition government. This would allow Canada to re-engage in the cap-and-trade system created by the Kyoto Protocol. In those circumstances, Canada would follow Japan's and the EU's lead and commit to a similar target.
- Russia and Ukraine sign up for targets that begin to cut into the excess allowances that the current Annex B list of targets provides. We assume that Russia and Ukraine will negotiate a target reduction that runs parallel to that of the EU from 2010 to 2020.
- Former Soviet and Yugoslav republics that are not in the EU are assumed to take on targets to not exceed 1990 emissions.
- No participation of developing countries.

Notes on the scenario:

- The scenario expects that the new US administration fails to secure congressional approval on national binding emissions reductions. We expect that with a change in administration, congress could begin to debate proposals for a federal emissions trading scheme as early as 2009. However, either congress agrees on a national emissions trading scheme with a low level of environmental ambition (easy target) or does not adopt a national cap that takes affect ahead of 2020.

Table 6.1 *Targets under Scenario A: 'Kyoto as usual' - key assumptions*

	% of global emissions covered 2006 [%]	% of global emissions covered 2022 [%]	Global target in 2020 [% on 1990]	Assumptions	Operational markets
EU	16	13	80	EU retains leadership role	EU ETS
Other Annex I	16	14	Varying target ranges	Kyoto Protocol parties agree new round of caps	GIS, JI and possibly internal emissions trading schemes
US	-	-	-	Positive signals, no target yet	-
China	-	-	-	Positive signals, no target without US	Increased CDM
India	-	-	-	No target	Increased CDM
Other non-Annex I	-	-	-	No target	Increased CDM

Figure 6.1 refers to Scenario A and shows cumulative supply of CERs and ERUs assuming three different carbon price levels; € 15, € 35 and € 65/tCO_2-eq. It is a measure of the potential supply given certain demand expectations. We find that where the carbon price is € 15 the credit supply from greenhouse gas emissions reduction projects is 8.4 GtCO_2-eq. This figure rises to 14.7 GtCO_2-eq where the carbon price reaches € 35 per tonne, and 16.6 GtCO_2-eq at a carbon price of € 65 per tonne, corresponding to 1.0, 1.8 and 2.1 Gt per year on average over 2013-20.

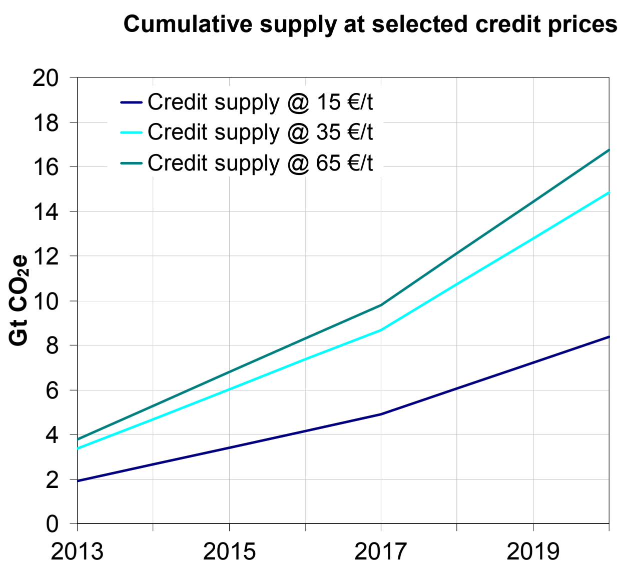

Figure 6.1 *Scenario A: cumulative CER/ERU supply*

6.2.2 Snapshots of the market in 2020 for Scenario A

In Scenario A, the market grows in stature only slightly compared to the Kyoto Protocol commitment period. The same actors are present, with Canada and Japan the only non-European major buyers of credits. Within Europe, governments and the private sector continue to compete for credits from the Clean Development Mechanism and Joint Implementation.

Some governments on the buy-side could be expected to decide to limit the investment in CDM projects as has been implied for ongoing negotiations today[19]. This is intended to pressure developing countries to take on commitments of some kind beyond being recipients of foreign direct investment through the CDM. It may also be more acceptable to voters that governments pay for (or allow their private sector to buy) credits from countries that already have caps, through Joint Implementation or green investment schemes instead of the CDM.

On the other hand, it is reasonable to expect some changes to the EU ETS from its current composition. Credits could be accepted from a wider range of project types, including certain LULUCF projects for example, as a result of the ongoing review of the EU ETS. Similarly, it is reasonable to expect a role for carbon capture and storage in the scheme, either integrated into the EU ETS as a negative source or as a provider of external credits.

The European Commission is considering an extension of the trading phase in the EU ETS to run from 2013 to 2020 inclusive, rather than the five-year term (2013-2017) foreseen in the relevant directive[20]. This could be integrated into the international system if it evolves beyond simply an extension of the current Kyoto Protocol system. An alternative would be to negotiate two commitment periods (or trading phases in the EU ETS) at the same time, so that there is certainty for private sector investments out to 2022.

With Japan facing a change in a second Kyoto commitment period compared to its target in the first, but in the context of little change internationally, there may not be a radical shift in domestic policy but rather a continuation of the system of negotiated targets for the industrial sector with the door held open to credits created under CDM and JI.

Canada on the contrary is more likely to revert to its original plan of a national emissions trading scheme for large fixed-point emissions sources and a gateway to the international emissions trading system. This was the blueprint established by the Liberal Party before it lost government in 2006 but may be so in the future again. However, again there is public resistance to relying on emissions reductions elsewhere to meet domestic targets, as well as to vast expenditure of taxpayer money on credits from countries that do not have emissions restrictions themselves. Thus there could be a limit on the scope for international emissions trading, such as a cap on the use of imported credits or a buy-out price level as has been considered in Canada under the previous government.

The scope for linking between emissions trading schemes in Annex I countries remains very limited. While there could be links between the EU and Canadian systems, and indeed between the EU and the Regional Greenhouse Gas Initiative or a future West Coast scheme in the US (in the absence of a federal emissions market), the prospect is limited. A link between two systems requires legal alignment, equivalency in environmental ambition and accounting stringency and pricing levels that would create benefits for traders who straddled the two markets. Bringing about these three aspects in Scenario A seems unlikely.

The Stern Review on the economics of climate change, published in 2006, says of emissions trading schemes: “Broadening the scope of trading schemes will tend to lower costs and reduce volatility. The next 10 to 20 years will be a period of transition, from a world where carbon-

[19] Conversations with EU member states delegations, July - December 2006.
[20] Conversations with EC officials, Eurelectric officials, March 2007.

pricing schemes are in their infancy, to one where carbon pricing is universal and is automatically factored into decision making.[21]"

However, without the potential or need for linking emissions trading schemes and with a restricted project market and only incremental increase in demand across the Kyoto system, it seems unlikely that in this scenario a single price for carbon would emerge. Rather, a continuation of the status quo where systems remain isolated (e.g. New South Wales in Australia) or only partially connected (EU ETS and CDM) seems more likely. Given this and the different pricing mechanisms in the opaque CDM market, a single price for carbon may be beyond reach in Scenario A.

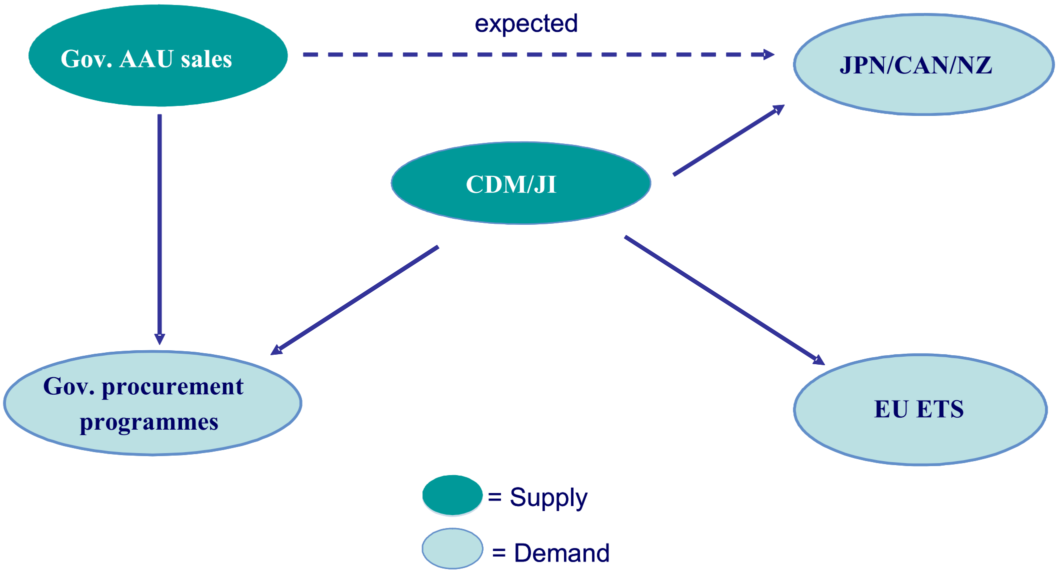

Figure 6.2 *The Kyoto architecture in 2020*

6.3 Scenario B

6.3.1 Assumptions

The key premise in Scenario B is that international negotiations enjoy complete success and all major emitters including the largest developing countries accept environmentally ambitious targets (lower caps on greenhouse gas emissions) to kick in from 2013. The key to unlocking the international negotiations and opening the way for an ambitious new agreement with wide coverage and tight caps on emissions is the participation of the US. While some progress may be made before 2009, negotiations are unlikely to be particularly productive before a new US president takes office.

Scenario B depends on two crucial developments. The US federal Government would make climate a priority by enacting strong domestic reduction policies and exert pressure on other major emitters, notably developing countries, to follow suit; and China and other advanced developing countries must agree to take on absolute quantified emissions reduction targets, giving up their opposition in the face of strong pressure from the US and the rest of the international community. Of these, a US policy shift is the most fundamental, as it is highly unlikely that China would agree to targets before the US.

[21] Stern Review: The economics of climate change, executive summary page xviii.

In this scenario, we assume:

- A sense of political urgency in the US and rapid development of a new federal climate policy in 2009, following the election of a more environmentally aware administration. The new President takes positive action by introducing a national ETS and re-engaging with international negotiations on a new protocol to replace, or supplement, the Kyoto Protocol - though still involving absolute caps on greenhouse gas emissions.
- The US agrees to binding emissions targets with some level of ambition, for example in line with the bill with the most seniority in Congress, the Climate Stewardship and Innovation Act (CSIA). The CSIA aims to bring GHG emissions to 2004 levels by 2012, to 1990 levels by 2020, to 22% below 1990 levels by 2030, and to 60% below 1990 levels by 2050. It would also allow companies to use offsets to cover up to 30% of their emissions in a programme very similar to the Clean Development Mechanism. It proposes a federal cap-and-trade scheme that will cover electric power, industrial, commercial, and transport sectors. The CSIA has been introduced three times, most recently in January 2007, and is more widely known as the McCain/Lieberman bill. It has since garnered the support of nine legislators and now has the support of three main candidates for the 2008 presidential election.
- The aggressive US policy on emissions reduction then encourages all of the OECD, a few emerging-economy OECD members (Israel, Mexico, South Korea) and other advanced non-Annex 1 countries (Turkey, Kuwait, Singapore) to take on emission caps, given their advanced stages of development and, in several cases, high per-capita emissions.
- China takes a cap based on its projected 2020 emissions. We set a uniform target for China at this level for the entire 2013-2020 period, demanding no gradual reductions within the period covered by our scenario. Given the instability of the cap in the early years, from 2013 on, China will be able to sell surplus AAUs insofar as it does not emit more than its cap. After then, however, the target will start to make itself felt unless cuts to the BAU are made. This formula of allowing for surplus AAUs in the first commitment period was effective in incentivising Russia and other eastern European countries to take on targets under Annex B of the Kyoto Protocol. However, this does mean that China's participation implies that it has surplus AAUs to 2020 and loses eligibility for CDM but gains it for JI. China could be confirmed to be the world's largest emitter of greenhouse gases by the end of 2007. Given this, it is unlikely that China will agree to cap its emissions with reference to a past date such as 1990 or 2000, given the country's ample output and emissions growth. However, it is more likely to expect to see China taking on targets based on a future projected emissions level, endeavouring to halt the growth in its emissions beyond the timeframe of this study.
- In the context of a new international consensus, the EU lifts its level of ambition in line with its 'multilateral' policy of a 30% reduction on 1990 levels by 2020.
- Some other rapidly developing East Asian economies, such as Malaysia and Thailand, take on targets based on their 2025 BAU emissions.
- The remaining developing countries have no commitments in the 2013-2017 period. However, from the 2018-2022 period, India and a number of other large developing countries with low per capita emissions join the international climate regime with targets based on 2030 BAU emissions. The countries joining India in this scenario are Indonesia, the Philippines and Pakistan. These targets may well turn out to cover only parts of the economy such as the power sector, or be 'upside-only' targets, but in our scenario modelling we treat them as if they were absolute Annex I-style caps. In the case of India, we assumed a cap of 280% of its 1990 level emissions, and estimate its actual emissions in 2020 to be 251% of 1990 levels, leaving a surplus of 483 MtCO_2-eq in AAUs. For Indonesia, the surplus is 133 MtCO_2-eq, for the Phillipines 26 MtCO_2-eq and for Pakistan 28 MtCO_2-eq.

Table 6.2 *Table Scenario B - 'Global reach' key assumptions*

	% of global emissions covered 2006 [%]	% of global emissions covered 2022 [%]	Target in 2020 [% on 1990]	Assumptions	Operational markets
EU	16	13	70	Maintains commitment to deep cuts	EU ETS
Other Annex I	16	14	Varying target ranges	New, deeper commitments	GIS, JI and possibly internal emissions trading schemes
US	23	21	86	Takes leadership role on climate	National ETS established
China	16	21	356*	Takes on target	CDM converted to JI/GIS/internal abatement, possible national ETS
India	4	5	434*	Sectoral or no-regrets targets likely	Mechanism similar to JI
Other non-Annex I	-	-	Varying target ranges	Follow Chinese or Indian model	Follow Chinese or Indian model

** Baseline 2000.*

Figure 6.2 shows supply under Scenario B, showing tighter caps across the board, with the US and China both taking on a target by 2020. Given these expectations of increased demand, the level of supply rises to 9 $GtCO_2$-eq (cumulative over 2013-2020) at € 15 per tonne, 16 $GtCO_2$-eq at € 35 per tonne and 18 $GtCO_2$-eq at € 65 per tonne. On average the supply would be 1.1, 2.0, and 2.3 $GtCO_2$-eq per year respectively.

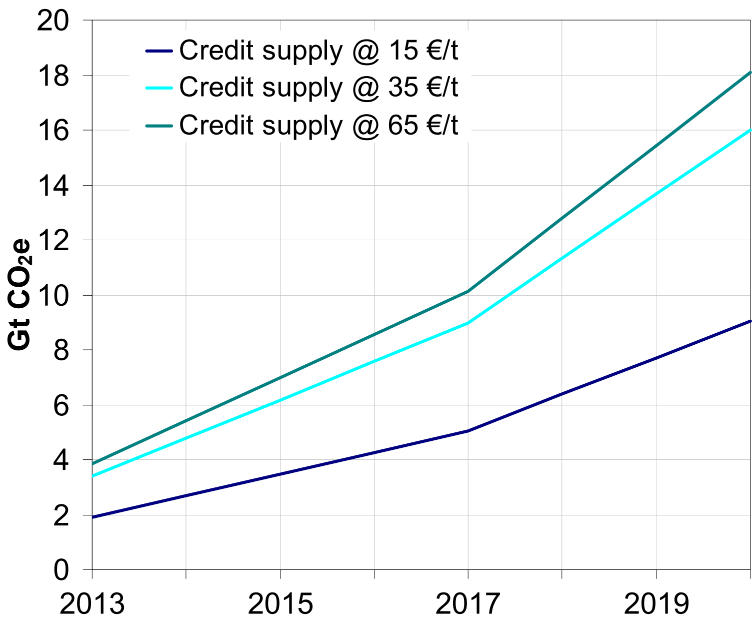

Figure 6.3 *Scenario B: cumulative CER/ERU supply*

6.3.2 Discussion of results from Scenario A and B

The scenarios are differentiated by an assumption that the scenario combinations which offer the largest potential credit demand are those which prompt the greatest potential supply and vice versa. Thus, we note that potential supply by 2020 in Scenario A is less than Scenario B. We make this assumption on the basis that:

- The larger the targets and the greater the numbers of participant countries in the market the more funds to drive innovation and achieve emission reductions.
- The more new technologies are used, the faster economies of scale can be achieved in manufacturing and in project development. This helps increase the profitability of projects and increases the number that are eventually completed.

We assume that the largest increases in credit supply occur at the end of the forecast period when emission reduction technologies become more established and commercially viable. For instance, it is expected that carbon capture and storage (CCS) from large emitting installations is not likely to be commercialised until after 2020. In addition, a number of renewable technologies (such as wind and tidal) are likely only to be commercialised well after 2020 - and these have the potential for quite significant levels of credit supply. We also expect technological development to provide further emission reductions at a variety of price levels the further we move ahead in time.

The difference between Figures 6.1 and 6.3 is 2 $GtCO_2$-eq cumulatively. On detailed exploration of the GCP model's behaviour in yielding this output, it became apparent that this corresponded to the expected demand from the US (2.0 $GtCO_2$-eq in 2020). In our political scenarios, the reductions in the US are limited to a return to 1990 levels by 2020. China adopts a range of targets that would allow a shortfall of just 46 $MtCO_2$-eq from business-as-usual emissions in 2020, with real reductions required further down the line. It still has the possibility to sell its AAUs where it can link them to environmental projects under green investment schemes or Joint Implementation, considering its relatively low marginal abatement cost. Therefore, it is only after 2020 that the impact of China's presence in the market as an Annex I country reaches its full extent.

6.3.3 Comparison with Chapter 4 results

The quantitative results in this chapter can also be compared to other estimates of the credit potential in this report. In Chapter 6 the Point Carbon approach to estimating the supply of CERs in Scenario A and B has resulted in a supply curve, which can be summarised as done in Table 6.3.

Table 6.3 *Point Carbon CER supply estimates*

Price level	CER supply in $GtCO_2$-eq/yr (average per year in 2013-2020)	
€/tCO_2-eq	Scenario A	Scenario B
15	1.0	1.1
35	1.8	2.0
65	2.1	2.3

These figures do not represent the maximum economic potential, but can be seen as an attempt to estimate a more realistic CER supply (see Section 6.1). The supply of credits depends, among other factors, on the expected demand. As in Scenario B the demand for GHG reduction is larger, the supply reacts and also increases, although with some delay to allow for the lead-in time in project development.

These estimates can be compared to the results in Chapter 4, which represent the market potential for CERs in 2020, taking into account barriers to CDM projects. It can be observed that the Point Carbon supply figures for price levels 35 and 65 €/tCO_2-eq are in the same range as in Scenario 1, 2 and 3 in Chapter 4 (see Figure 4.2). Scenario 4, as the most 'optimistic', yields higher supply than projected by Point Carbon. Another difference is the lower supply at 15 €/tCO_2 compared to Scenario 1 to 4, indicating fewer low-cost options according to Point Carbon. Overall it can be concluded that both Point Carbon's supply curves are lower than the results in Chapter 4, which is also due to their assumption of commercialisation of CCS and further improvement of wind energy after 2020. The bottom line is that these figures indicate that the market potential could be significantly smaller than the technical potential, and that the degree of uncertainty related to future supply of carbon credits is considerable.

6.3.4 Market outlook in Scenario B

In Scenario B, the market in 2020 will be much broader in scope than is currently the case. Emissions trading will encompass the US, source of over a fifth of the world's greenhouse gas emissions[22] by 2020. Even if the US has not ratified the expected protocol by that time, against expectation, it should have established a nationwide emissions trading scheme with links to the international market via imports of project credits from the Clean Development Mechanism and Joint Implementation[23].

Australia and New Zealand both expect to have established national emissions trading schemes with similar links to the global carbon market by 2020[24], and Canada may follow suit. In this context, Japan's hitherto reluctance to create a national emissions trading scheme may change in reaction to tougher targets and to a more liquid and efficient international market. There is support in Japan for an emissions trading scheme from the Environment Ministry, whereas the Ministry for Economics, Trade and Industry has resisted all moves to consider establishing a mandatory national scheme.

It is also likely in this scenario that some of the newest Annex I / Annex B members such as South Korea create national emissions trading schemes designed to mesh with the international system. Indeed, some elements in the Russian government and civil service promote a national emissions trading scheme, even as they expect to be net long in the scheme. It is seen as a means of driving emissions reductions by focussing investment to projects internally and thereby attracting foreign direct investment.

By this measure, China would be expected to create its own internal emissions trading scheme, although it is unlikely to be implemented before 2020.

With emissions trading schemes in place in US and Canada, the EU, Japan, Korea, Australia and New Zealand - and possibly Russia - there would be great advantages to linking the schemes. While the legal, technical and political barriers would still have to be overcome, there would be greater opportunity for arbitrage between price levels across the schemes.

In this scenario, the market for credits from greenhouse gas emissions reduction projects would increase considerably in stature from Scenario A. There are important differences, in that the number of countries eligible to host CDM projects is reduced, notably with China switching to the JI / GIS sphere. With its low marginal abatement cost, it is possible that Chinese entities would be incentivised to reduce emissions even if the country has a target equivalent to business-as-usual.

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22 Energy Information Administration, international greenhouse gas emissions data.
23 The Carbon Market in 2020, report to be published by Point Carbon Q4 2007.
24 Australian Government Department of the Environment and Water Resources, www.greenhouse.gov.au, and New Zealand Treasury Emissions Trading Group, www.climatechange.govt.nz.

As the coverage of emissions trading schemes increases worldwide, concerns with leakage, i.e. polluting industry moving to non-capped areas, will diminish. Combined with stronger evidence of the effects of global warming, this will justify tighter targets.

The increasing diversity in the global carbon market - combining different sectors in countries at different developmental stages and with very different marginal abatement costs - will realise the economic potential of emissions trading better than currently seen in the EU ETS. It will also be positive for liquidity and contribute to an increase in traded volumes.

However, there will be political concerns with abatement being concentrated in a few countries or a few sectors if caps are set very differently across countries and sectors. Until such concerns are addressed, there may be restrictions on the transfer of allowances across schemes[25]. There will also be some buyer countries that find certain technologies and project types unpalatable and may exclude them from their national system, as is currently the case for example with LULUCF projects and the EU emissions trading scheme. Gradually, however, we expect that carbon prices across the globe will converge over time.

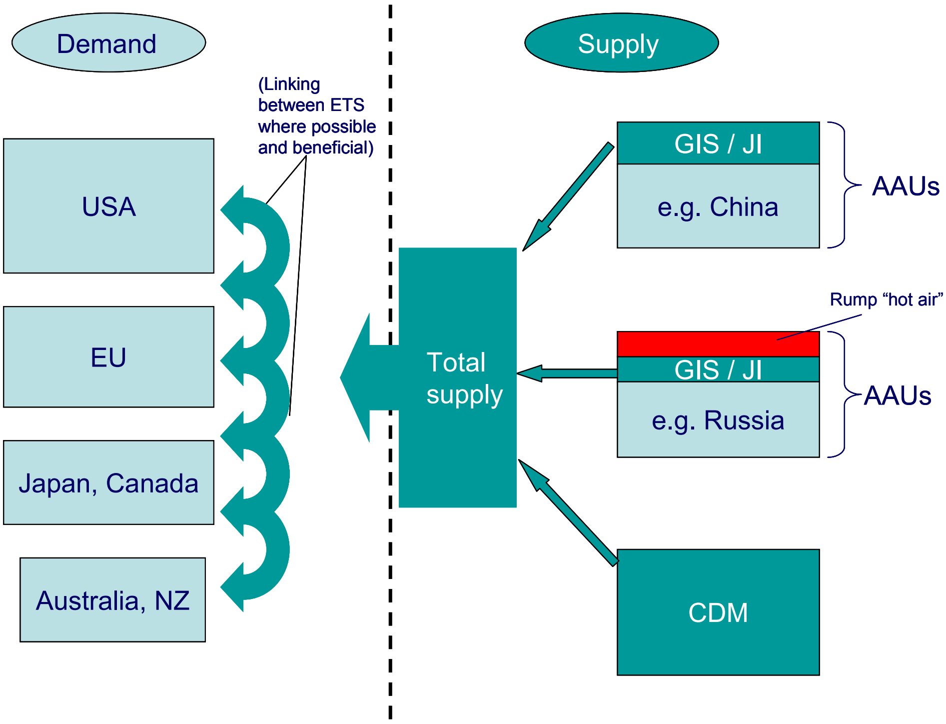

Figure 6.4 *Supply and demand in Scenario B*

Figure 6.4 is a schematic of the possible market under Scenario B. In this market, supply comes from the project-based mechanisms as well as those AAUs which are brought to market and linked to emissions reduction or general environmental projects under a green investment scheme. Those AAUs which are not 'greened' are called 'rump hot air' in this diagram, marked by the red bar here and assigned to Russia, purely as an example. The 'rump hot air' is banked for future phases, or lost if there are any changes to the scheme between now and 2020 that prevent such banking.

6.4 Scenario C

In the third scenario, some countries outside the current Kyoto sphere, the US in particular, set national targets and allow for VERs to be used for compliance. It may develop its own standards

[25] Point Carbon, Carbon Market Monitor September 2007.

for voluntary offset credits or adopt one already established by industry. The standards would have lower additionality and other criteria, although this scenario envisages some intrusion into the regulated market; that some project credits are diverted away from the internationally regulated market into the US and other jurisdictions where there is demand for voluntary offsets, including the EU. This is currently the case, with some offset retailers selling gold standard CERs to voluntary offset clients. One would expect this to increase dramatically.

The US plan would involve a national emissions-trading scheme, for example either with voluntary target or mandatory target set at a relatively unambitious level, such as an intensity target. The importation of credits from abroad would be allowed to meet targets in this system. This would not be enough for the US president at the time to bring it to the international negotiating table and persuade the Kyoto parties that it is participating in a meaningful way[26].

As a result, the US scheme would be large in stature but distinct from the internationally regulated market. The notable characteristic of this scenario is that it presents a choice for project developers. They may sell credits from projects that reduce emissions into the regulated international market, or into the voluntary US market.

The current market already provides that choice. For example, a wind farm in Africa may choose to sell voluntary credits up front to a voluntary offset provider, an intermediary, e.g. based in the Netherlands. The wind farm developer will face lower validation costs and transaction costs and could deliver credits and be paid upfront for future reductions, depending on the contract negotiated with the buyer. As the price and financing are established now, the price risk is minimised.

However, typically a voluntary offset credit is now worth less than an issued CER, so the project developer faces less upside to his strategy.

Alternatively, that project developer could sell CERs on a forward basis. There are several disadvantages compared to a sale into the voluntary market. While the contract could be booked to the economic advantage of the seller, usually the payment is on delivery, so the project developer would have to wait, possibly years, before accruing the cash. The price the developer secures for its CERs in the CDM market reflect the proportion of risk it is willing to assume in relation to the buyer. If it can afford to wait and has the appetite for risk, ultimately the developer could sell its CERs after issuance for which it would command a price level indexed to the EU ETS, currently around 75-80% of the prevailing EU market price. However, the developer faces the risk of the project not performing or not being registered by the CDM Executive Board.

Some project developers may opt to sell their CERs on a forward basis, only marketed as VERs until the project is registered. In this way they are securing interest from a buyer and ensuring income at a minimum level, while keeping the possibility open for higher returns if the project is registered. In this case, the VERs are considered pre-issuance CERs.

Conceivably, the draw from the US on global emissions reductions could include voluntary projects in Annex I countries, although it seems more likely that countries with tough emissions reduction targets would disincentivise their export to the US. In that case, projects that do sell VERs to the US would most likely not meet the standards set in the internationally regulated market.

It is not considered likely that countries that have ratified the Kyoto Protocol and are engaging in negotiations on another round of targets would accept the US effort based on voluntary emissions reductions as equivalent to an Annex B-type target. The US level of ambition would

[26] Post-2012, the outlook for carbon and energy markets, published by Point Carbon October 2007.

be low in this scenario and it would be politically more acceptable for the authorities to incentivise the acquisition of VERs from domestic projects. This is currently the case for RGGI, where different price levels would trigger the opening of gateways to credits from the RGGI territory in the first place, then from the US in general, then internationally as the price rises[27].

For these reasons it is reasonable to expect the US demand for voluntary credits to be limited in relation to its expected demand for credits in Scenario B. Similarly, in Scenario B, the participation of the US implies increased demand for CERs and ERUs. In this scenario, on the contrary, demand in the regulated system is withdrawn even as the potential supply of credits is split between the voluntary and regulated markets. For this reason, it is possible that the net effect of Scenario C on the total project credit supply to the regulated market is limited.

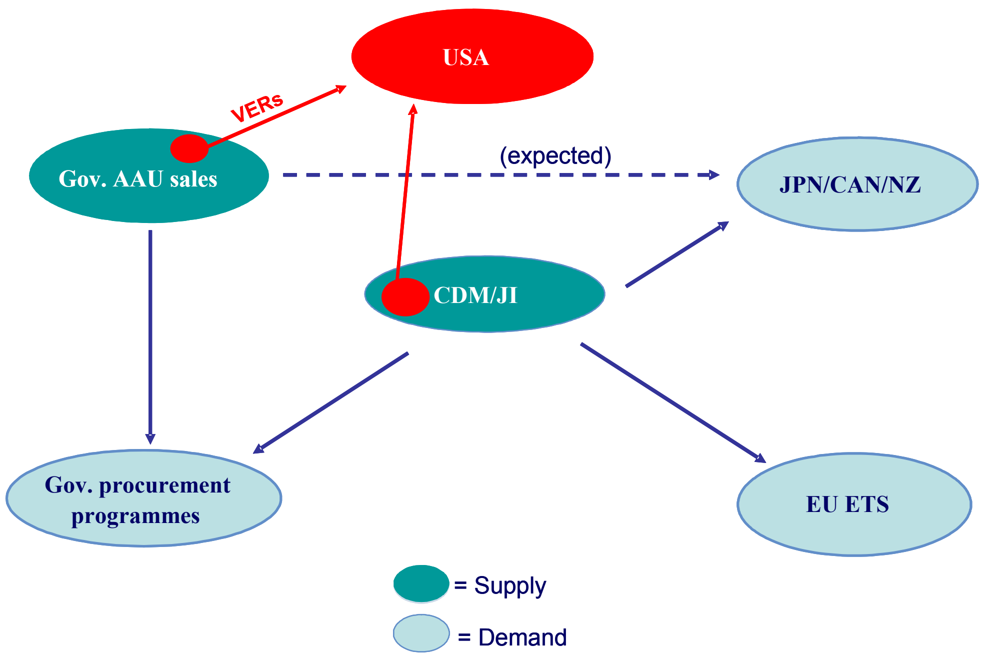

Figure 6.5 *Scenario C with VERs*

6.5 Summary and discussion

The outlook of the carbon market after 2012 is highly uncertain, with six years to go to resolve all outstanding political and technical issues. Demand for credits depends on targets for Annex I countries. Those for the period 2013-2020 are subject to the outcome of ongoing negotiations. The picture changes considerably from our first scenario to our second; from a continuation of the current situation with no progress on expanding the list of countries in Annex I, to a rapid roll-out of targets to a list including the world's two biggest emitters, US and China.

A third scenario is also possible (but not considered likely), where voluntary credits gain a more official status. In which case there will be competition between VERs and CERs for several technologies.

In our consideration of future demand, we have used any spare AAUs first to meet that demand, before applying our assessment of the expectation of demand. It is that expectation that drives the flow of credits from project credits, due to their lead-in time. If there is expectation of strong demand and high prices, then project developers are expected to ramp up their activities and supply increases. The next step is for this supply to dampen prices, although future prices are not modelled in this project.

[27] RGGI Model Rule, subpart 10, CO_2 emissions offset projects.

A scenario where there will be different segments in the carbon market is perfectly possible, as is a scenario where most of the market corresponds to a single price for one tonne of CO_2-eq. Linking between regional markets can differ in nature, from direct links where credits are fully fungible across more than one system to indirect links, where for example separate systems all draw on project-based credits. If countries currently not included in Annex I take on (no-lose) targets there may be additional supply of AAUs post-2012. This could be in the order of several $GtCO_2$-eq/yr in the first years after 2012, and decreasing thereafter, e.g. if targets for the period 2013-2020 are set to BAU emissions in 2020.

7. Procurement

Governments in the EU, among themselves, have built considerable experience in procuring credits in the project markets created under the UNFCCC and Kyoto Protocol. The experience has been varied in success, whether judged by number of credits per capital committed, or developmental benefit and matching with overseas development aid goals.

The post-2012 phase provides an opportunity for sovereign buyers to consider the performance of their procurement programmes to date, and to tweak their focus or overhaul their programmes completely in the light of the experience gained.

7.1 Options available

This section considers the options available to a prospective governmental buyer of carbon credits in the current market, in decreasing order in terms of the level of involvement of the buyer.

7.1.1 Direct Investment in projects

The contract to transfer ownership of a CER from seller to buyer is known as an Emissions Reduction Purchase Agreement (ERPA). As the initial CDM contract is much like project finance, ERPAs vary from case to case. Typically, however, the price agreed in most primary ERPAs is a function of the apportionment of the various risks inherent in generating a CER and delivering it to the buyer, as well as contractual issues.

The risks are grouped as follows:
- Performance risk (financial, technical, counterparty related).
- Registration and revision risk (project approval, baseline and methodology from the UN).
- Host country risk (general and carbon related).
- Contractual issues.

Performance risk
The performance risk relates to how the project performs in relation to expectations:
- whether the developer will obtain financing to build the plant,
- whether the plant will operate as foreseen in the project plans and the expected number of CERs are issued to it, and
- the creditworthiness of the counterpart.

Registration risk
Registration and revision risk relate to whether the project is registered, and then approved, by the CDM Executive Board. The emissions reductions, which determine the number of CERs the project is issued, depend on what ‘business as usual’ scenario the CDM authorities decide is appropriate to judge the project (baseline risk) and whether the project is considered to be additional. The project must be executed according to a ‘methodology’ which in turn must be approved by the CDM methodology panel.

Country risk
Once these challenges are overcome, the issue of the investment climate in the country hosting the project remains.

Contractual issues
It is also noteworthy that each ERPA contract may have different provisions that affect the price. For example, where buyers are willing to commit to upfront payment they will command a lower price than in the case of payment on delivery. Similarly, a higher price will be paid by one company seeking to be the preferred claimant if a project with several buyers underperforms. That company will pay more to be the first in line to receive CERs if there are not enough for the seller to meet all of its obligations.

To receive credits from a project, investors need to be named as a project participant. Depending on the stake in the project this will involve investing a certain amount of capital (this amount is also dependent on the level of upfront cash required for the project). This means that investing directly in projects is often not possible for smaller players. There are also considerable risks, especially investing in projects at an early stage of development, so this means that the investing company should be able to absorb potential losses or a shortfall in delivery from defaulting/low-performing projects.

Several entities have held auctions of CERs from various projects using online platforms. The typical format is where, at the end of the auction, the winning bidder and the seller enter into negotiations over an emissions reduction purchase agreement (ERPA) on a bilateral basis. The negotiations are structured to varying degrees by the hosts of the exchange, although their participation beyond that is limited. The buyer and seller are not bound to conclude the ERPA.

7.1.2 Purchasing on exchanges
There is a secondary market for issued CER credits, both over-the-counter and on several exchanges. The terms and conditions for trading these products are similar to others on the exchange. Advantages include: pre-determined creditworthiness of the counterparty, or indeed the counterparty may be a clearing house or clearing member; price transparency and anonymity and in some cases the need to place a margin deposit rather than pay or assign the full sum to be paid.

This market segment is more suitable for mid-sized players although the prices of issued credits are higher than for credit purchase agreements at earlier stages in the project pipeline. Smaller participants may find exchange fees and conditions to be excessive for their needs, as for them the over-the-counter market may be more accessible.

7.1.3 Participating in funds
A large number of carbon credit funds are now in operation. These vary considerably in terms of target investors (public or private), cash-return or credit-return, type of credits etc. The World Bank manages a variety of public-private mixed funds as well as closed funds on behalf of its sovereign clients, such as the World Bank Spanish Carbon Fund. This section of the report considers those funds that are open to wider participation, focussing on private sector funds.

Many of the funds are open to investors of all sizes (i.e. the minimum investment amount is not too high) although there are some that require significant upfront investments, which would exclude many smaller players. Fees are either based on percentage fees or as fixed management fees (which may disadvantage smaller investments). It is possible, however, for smaller players to participate in funds through a financial intermediary, which may be catered more to smaller investment sums.

The rise of the fund is a noteworthy trend in 2007, with a sharp increase in the number of proprietarily managed funds taking long-term positions, rather than servicing clients. While estimates of the amount of buyers of CERs vary, one UK-based analyst suggests that as many as

100 companies are active in buying carbon credits in China - the largest market for CDM projects - with financial institutions from Europe and Japan accounting for half that figure.

Their presence is seen as driving up the range of prices at which CERs are placed under contract. Buyers of primary CERs are even said to be paying up to € 14 - 15 per credit in some instances. These transactions at the higher end of the scale are € 1 - 2 above what has been quoted in the market over the past year for credits from projects registered by the CDM executive board.

The nature of the funds vary to such an extent that it is hard to find two funds with the same structure, procurement policy and target internal rate of return. Point Carbon's database lists 33 carbon funds, including public sector funds and those that pay out in cash rather than carbon credits. The data pertaining to each fund is approximate and subject to change. The total capitalisation is now around € 5 billion, an increase of almost € 2 billion since summer 2006.

There are another 11 private-sector funds in the pipeline, which could launch this year or next. It is also reasonable to expect more public-sector funds as governments confirm their procurement plans with a view to meeting their Kyoto targets.

Investors in funds must be wary that what empirical evidence there is in a relatively new market suggests that CDM project types perform at varying rates, delivering over 100% of the declared volume in the PDD to as little as 18%. Fund managers must contract for more than they require to hedge this risk. Thus, for the investor there are still levels of risk from which to choose, depending on the management strategy of the fund.

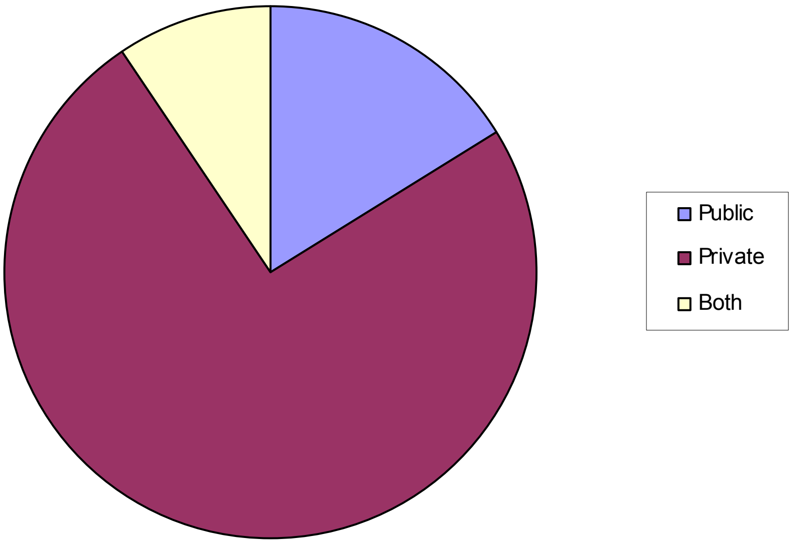

Figure 7.1 *Carbon funds in Point Carbon database, by capitalisation*

Table 7.1 *Carbon funds with over € 100 million in declared capitalisation in Point Carbon database*

Administered by	Public/Private	Total Cap (€ m)
Climate Change Capital	Private	830.0
World Bank Umbrella	Public/private	526.9
Natsource - GGCAP	Private	455.0
Trading Emissions	Private	438.0
Merzbach	Private	400.0
World Bank - Spanish carbon fund	Public	201.7
World Bank - Netherlands carbon fund	Public	191.6
EBRD	Private	165.0
Core Carbon Group	Private	152.0
IXIS - ECF	Private	142.7
World Bank - PCF	Public/private	128.6
Ice Cap Ltd	Private	120.0
World Bank - Italian carbon fund	Public	111.1
Japan Carbon Finance	Private	110.0
Carbon Capital Markets	Private	100.0
ICO Santander	Private	100.0
RNK Capital	Private	100.0

Source: Point Carbon database. All information is gathered from the funds in question. Pont Carbon strives to keep the data up-to-date, but assumes no responsibility for the accuracy of the data, which are subject to change.

7.1.4 Outsourcing carbon price risk to a third party

Particularly for the smaller participant in the carbon market, several companies and financial institutions offer to fully manage the carbon price risk that a company faces. In general they offer grades of how actively managed the risk is.

Low risk, light management

At one extreme of the range, the service company may source those credits needed for compliance or sell any surplus once compliance has been assured, usually at a fee plus the market rate for the credit type in question. This grade may suit smaller participants such in the EU ETS, for example, which are dealing with relatively minor sums and do not have the credit basis or appetite for assuming market risk.

An important disadvantage to this level of risk management is that the buyer pays the market rate on the day of transaction, even if that is disadvantageous compared to an earlier or later period.

To mitigate vulnerability to price fluctuations in this case, some providers offer to buy or sell at a rolling average of the market rate, insulating the buyer from short term price spikes.

In some cases, the service providers act as counterparties to the client, minimising the administrative burden and constraints of being a smaller participant, including establishing terms with a third party. The service provider also offers to watch the daily fluctuations of the market and notify the client if the market rate arrives at the client's preferred level.

A buyer with risk aversion may opt to instruct the intermediary to acquire project credits with the lowest risk profile, e.g. those that have already been issued by the CDM Executive Board. In that case, the buyer could be paying the market rate for the resale of CERs in the secondary market, i.e. 75-80% of the EU ETS price, currently € 16.60 - € 16.75/tCO_2.

Medium-to-high risk
The next level is where the client gives the service company a mandate to actively manage their carbon risk on an ongoing basis, which enables the service company to seek to maximise profit or minimise cost.

In this case, the client hands over control of its credits to the service provider who adds it to its portfolio. The latter is then free to actively trade in the market, take short-term positions and hedge its exposure, with the client benefiting to a greater or lesser extent from any upside gain, or from the hedging of price risk to minimise the cost of a shortfall over the year, depending on the terms of the contract agreed with the client. The higher level of risk assumed by the client requires a stronger credit basis.

Figure 7.2 gives an overview of the different actors in the carbon market.

	Governments	Funds		Private
		Compliance	Profit	
Risk	Often take on a higher risk in return for a lower price	More risk averse	Risk seekers, invest early	More risk averse
Project type	Prefer CO2 reduction projects	Large industrial non-CO2	No clear trend	Large industrial non-CO2
Payment type	More likely to pay upfront	Payment on delivery	Payment on delivery but some upfront payment	Payment on delivery

Figure 7.2 *Different actors in the market*

7.2 Building a post-2012 strategy

EU member governments with procurement programmes for carbon credits up to 2012 will now be considering whether and how to adapt their programmes for the post-2012 phase. Uniquely, the EU has internal targets and an emissions trading system that reaches beyond 2012 (the 2003 EU Emissions Trading Scheme Directive) and allows participants to use project-based carbon credits for compliance purposes (the 2005 EU Emissions Trading Scheme Linking Directive).

While governments are not usually the operators of installations covered by the EU ETS, the long term targets under the EU ETS are derived from the EU's stated goal to reduce greenhouse gas emissions by at least 20% on 1990 levels by 2020. The linkage between the EU ETS and the project mechanisms serves to demonstrate the political capital that the EU member states have invested in such mechanisms.

Such governments would therefore be expected to draw on their experience, as well as on that of their European partners, gained in procuring CERs and ERUs up to 2012 when formulating their response to their procurement needs in the period 2012-2020.

This section of the report provides an overview of what certain governments in the EU have done to date, including Austria, Italy, Japan, the Netherlands and Norway. It goes on to draw conclusions on procurement strategies.

7.2.1 Extent to which procurement features in national plans

To what extent are governments currently the international offset markets (CDM/JI) to meet their Kyoto goals? This is illustrated in Table 7.2. The range here is from just 13% of the shortfall in the case of Japan, to 122% in the case of Norway.

It should be noted that Norway has a stated goal of becoming *carbon neutral* as a country by 2050, with extensive use of the CDM/JI markets to reach that goal. The Japanese government is also expected to gear up its procurement plans between now and 2012.

Table 7.2 *Government purchase plans*

Country	Invested [Mt]	Further budgeted [Mt]	Further planned [Mt]	Total to 2012 [Mt]	Kyoto shortage, BAU [Mt]	% short covered by procurement
Austria	37	0	8	45	106	42
Denmark	18	0.2	8	26	89	30
Italy	14	0	86	100	474	21
Japan	9	14	78	100	757	13
Netherlands[28]	58	43	0	101	200	51
Norway	1	3	66	70	58	122
Spain	60	0	100	160	518	31
UK	0	0	0	0	301	0

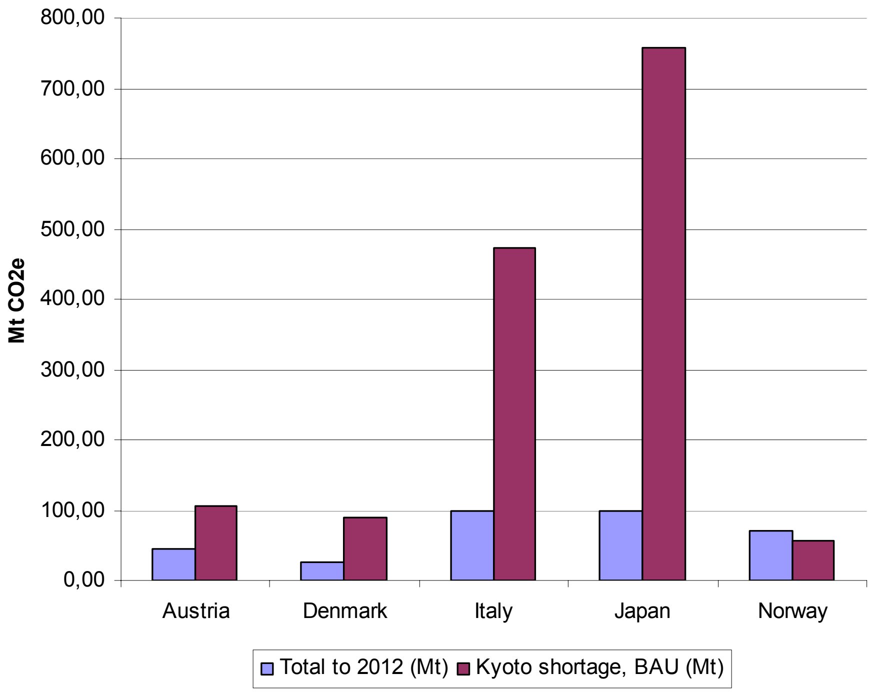

Figure 7.3 *Illustration of Kyoto Shortage compared with planned CDM/JI offset purchases*

[28] The Netherlands recently downscaled its procurement plans to 75 $MtCO_2$-eq to 2012, which would correspond to 37.5% of the shortage.

Notes on table and graph:

- The ‘Government purchase’ table shows the volume of CERs and ERUs individual governments already have contracted (Invested), have further budgeted for, and, finally, have further (concrete) plans for. The numbers include purchase of CERs and ERUs from single projects as well as investments in carbon procurement vehicles.
- In cases where only information on the amount of money (set aside in budgets) to spend on CDM and JI, not exact volume to buy, is available, volume is calculated on the basis of estimated future price and transaction costs.
- Several governments have indicated that some of the allocated funds will be spent on AAUs, some possibly at the expense of planned CDM/JI purchase. This has not been reflected in the table.
- The Kyoto shortage and BAU data are based on official statistics provided by the European Commission (EC) or the UNFCCC. For EU Member States we have applied data from SEC (2006) 1412, a document containing key data used by the EC in its NAP assessment. For the other countries we have used data from reports to the UNFCCC (Fourth National Communications or Reports on Demonstrable Progress under the Kyoto Protocol). The BAU 2010 estimates include only reduction effects of policies and measures implemented before 2004.
- The Kyoto shortage expresses the difference between the Assigned Amount and the BAU estimates for all countries.

7.2.2 Government paths to market so far

This section gives an overview of procurement strategies followed by Annex I countries up to 2007.

1) *Regular CDM or JI project tenders*. Pioneered by Austria, Finland, Sweden and the Netherlands, the tender process enables the government to retain complete control over the destination of its investments. It allows them to screen for projects in strategic locations that meet certain policy conditions. There tends to be some rigidity in the tender format, as governments must set conditions beforehand against which all projects are measured. The result is that sometimes they are precluded from making opportunistic investments in large, economically attractive projects. Also, the rigidity of a tendering process can have a negative impact on the buyer’s negotiation strategy. For example, too detailed indications on desired price levels yield corresponding offer prices.
2) *Small-scale CDM (SSC) tenders*, i.e. that specialize on small projects with high sustainable development impact. This method has been explored by Austria and Japan in part to circumvent the issue of rigidity in public tendering processes. It is too early to say whether these have been successful.
3) *Bilateral supply agreements with host countries.* The Netherlands has an agreement with Indonesia for the latter to supply a certain volume of CERs.
4) *Approaching private sector intermediaries*, such as financial institutions, brokers or aggregators to supply credits. The advantage here is that much of the effort in attracting and screening the prospective counterparties and negotiating the contractual issues can be outsourced. The obvious disadvantage is the brokerage / fee that the intermediary charges. This path to market was explored by the Netherlands and Rabobank in 2000 with limited success, due mostly to the lack of projects available and immaturity of the market. Now the market is more developed, a number of large financial institutions have built up carbon project origination and investment desks with large credit portfolios. The intermediaries seek to profit from the sale of credits to compliance buyers. A partnership agreement with an intermediary can lead to a low risk, ready supply of credits, however government buyers may incur higher costs due to the fees and the low risk profile of the credits. Denmark and Ecosecurities are exploring cooperation, although again the results are too early to judge the success of the cooperation.

5) *Combining overseas development aid (ODA) / technical assistance funds with procurement*. This is most actively pursued by Japan, but Denmark is also active. The OECD's Development Assistance Committee defined how this could be managed without breaching the rule that Annex I countries' CDM investments should not lead to the diversion of ODA. Point Carbon believes there could be scope for strong performance across the different policy goals of development, technical assistance and carbon procurement, especially if the buyer is involved throughout the whole project cycle. Sovereign buyers are able to exercise diplomatic leverage and garner local support for projects. For this reason, it implies greater coordination and project management on the part of the government in question, and a greater administrative cost than in the previous option (option 3 above).
6) *Buying credits on the secondary market*. This is under consideration by at least one European country as part of a wider procurement strategy. The advantage is that the volume to be delivered is firm, unlike most of the other procurement methods (see above). The risk of non-delivery can be reduced considerably if the government in question's counterparty is a financial institution with good credit rating, as is often the case. The main disadvantage is price, as the low-risk credit commands are higher value than investing directly in a project at an early stage in its development.
7) *Create a tailored procurement fund*. The Netherlands already has direct experience of this through its World Bank Netherlands fund. Other countries with sovereign funds managed by the World Bank include Denmark, Italy and Spain. The World Bank has close to € 550 million under management for sovereign clients in the country-specific funds. The advantages include outsourcing the administrative burden, relying on the World Bank's reach and expertise, combination of flexibility within a specific mandate, such as risk profile, price or volume, geography or technology, etc. One possible disadvantage is that there is little guarantee of fully delivering on the target volume, although this issue is shared with other procurement methods described here and may well be less acute in the case of a World Bank-managed, tailored fund.
8) *Invest in a fund open to other investors*. Examples include the World Bank's Prototype Carbon Fund (PCF) or Umbrella funds, where there is no national scope to investor requirements. The fee paid to the Bank may be less if shared among other investors, which is an advantage. However, it also implies less control over the criteria that the fund applies to its projects, plus the performance of the sovereign client's investment would be open to the other fund investors. In the cases of the two funds mentioned here, the PCF is considered to be slow to act due to the involvement of so many clients. By contrast, the Umbrella fund is a high-risk vehicle which has invested in just a few very large CDM projects[29]. There is considerable risk of underperformance if, for example, one of these large projects undergoes an outage or experiences *force majeure* and fails to deliver according to the expected volume stated in the PDD.
9) *Devolve all procurement to the private sector*. The UK has decided not to procure carbon credits with public funding, nor does it have an approval mechanism for JI projects carried out in the UK. Instead, it has actively encouraged private sector procurement of credits. It has done this through two main policy decisions; firstly, it set a relatively restrictive cap on the emissions of companies covered in the National Allocation Plan, so there is a strong financial incentive for companies to invest in CDM and JI projects to comply with the EU ETS target. Secondly, it encourages companies to make CDM and JI investments with a pro-active Designated National Authority and other offices offering support to companies.

7.2.3 Taking the experience forward to beyond 2012

The range of government procurement programmes is now considerable and much experience has been gained. The trend has moved from relatively restricted mechanisms with narrow scope, to a range of different mechanisms within a broad strategy.

[29] This may change as the Umbrella Fund adds new trances, which is the plan, as the focus would then be on other project types, due to the unavailability of HFC-23 decomposition projects.

The UK is notable in its decision not to procure credits with public funds, rather to encourage the private sector to acquire credits through the various market mechanisms.

Generally, the challenge for those governments with procurement programmes has been establishing firm volumes of credits under contract, with many government tenders in particular falling short on their target volume to be delivered (such as the early ERUPT tenders held by SenterNovem and the Austrian JI tenders held by Kommunalkredit). This could either be due to limiting the purchasing scope according to geographic region and/or project type can in theory impact prices per credit lead to difficulties meeting volume targets.

Nevertheless, the early-mover governments succeeded in securing CERs and ERUs at early stages of development of the projects themselves and the underlying market in general. As such, they tended to be at advantageous prices, compared to today's secondary market.

The Netherlands was among the first EU countries to instate a national procurement programme for carbon credits. It began with public calls for tenders (CERUPT and ERUPT for CDM and JI projects respectively) in 2001. However, its early experience was that the system based on fixed tenders involved a certain amount of rigidity in the criteria for selecting the winning projects, which meant that some project developers tended to fall out during the process.

More recently, the Netherlands has introduced greater flexibility by allowing for JI project developers to submit their Project Idea Notes at any time. The negotiations on price and contractual terms and conditions can then begin on a bilateral basis between the Netherlands and the developer. One notable change is that the contracts are made on a bespoke basis for each new project.

The Netherlands has also created a World Bank-managed, closed fund called the Netherlands Carbon Fund. It has almost € 200 million in capital committed and has signed emissions reduction purchase agreements for over 20 million credits.

When many of these programmes were first established, the private sector had yet to build up its presence in the market. This is no longer the case; now there are many private entities that are dedicated to, or have departments dedicated to CDM and JI. Competition for carbon credits from such projects has increased accordingly.

The market for project credits post-2012 is still in its infancy. There is greater uncertainty and risk than the pre-2012 market, with the long term international regime 2012 subject to the successful outcome of difficult international negotiations. While the CDM most likely will continue in one form or another, there is no guarantee that JI will continue beyond 2012 if the international negotiations fail.

For this reason, pricing varies considerably. It is understood that the World Bank has offered as little as US$1.50 for CERs in the post-2012 period, while other private buyers have offered between € 3 - 5. Preliminary post 2012 price modelling by Point Carbon shows that the most likely global carbon price is between € 30 - 54/tCO_2-eq[30] which implies that there could be a significant market opportunity in buying early.

The World Bank is under no obligation to buy credits beyond 2012 except that some clients have specified expenditure beyond 2012 (40% of the procurement the World Bank conducts for the Italy Carbon Fund is invested in post-2012 credits), and that it has a mandate to develop the market.

[30] This price assumes a set of political and economic conditions and is subject to large fluctuations depending on the supply of credits to market. For more information on post 2012 price modelling please contact Point Carbon.

Entities in the EU ETS, on the other hand, can expect increasingly tight caps in the period after 2012 and can expect to be able to use CERs at least, if not ERUs as well, to meet those caps. As compliance buyers, they have tended to pay for lower risk, higher price credits than most governments. This strategy is likely to continue beyond 2012 and demand will increase as the third trading phase (2013-2017) approaches. For the time being, however, the risk after 2012 is such that many private sector compliance buyers are not ready to commit funds to acquiring carbon credits beyond 2012.

Another advantage that governments had in the early stages of the CDM was their extremely low counterparty risk compared to private sector investors, which would be attractive to sellers. While that is still the case and increasingly advantageous as competition for CERs and ERUs increases, the market has seen the rise of the financial institutions which also enjoy good creditworthiness.

The challenge for governments as they look to establish their procurement strategies post-2012 is to carry forward their early-mover advantage into the next stage. This may be achieved by the following methods, *inter alia*:

1. Act now, while the market is still immature and there is less competition from other buyers.
2. Seek to extend terms with the counterparties of the projects that are under contract at the moment. In other words, where a government has signed a contract to acquire CERs from a particular project up to 2012, an option to acquire any CERs accruing after 2012 could be added. This could leverage some of the advantage already gained in the current period into the post-2012 period. Such options are commonplace now, although they tend to be couched in an emissions reduction purchase agreement ahead of 2012, perhaps as a sweetener for the buyer.
3. Up-front finance of projects, where the buyer pays now for future delivery. This relatively high-risk method can achieve low prices compared to, say, guaranteed CERs. This strategy is the speciality of the Asian Development Bank. Austria offers up to 30% in up-front payment, Japan up to 50%. Often used earlier in the project stage, it enables projects particularly with high initial capital expenditure. Typically, upfront payment of 5-50% will give a rebate of 5-30% on the price paid for a comparable project with payment on delivery.
4. Increase presence on the ground, to originate prospective projects. This tactic has been employed by intermediaries and professional project developers as well.
5. Use diplomatic leverage and strategic relationships with host governments or organisations, to enable the scaling-up of projects in a sector or region.
6. Apply experience gained to build up a project pipeline in the JI market, which is still relatively immature compared to the CDM.

7.3 Summary

The Netherlands was among the first EU countries to instate a national procurement programme for carbon credits. More recently, the Netherlands has introduced greater flexibility through its tenders, as well as creating a World Bank-managed, closed fund. The evolution in the path to market chosen by the Netherlands has taken it from cooperating with an intermediary (although at a stage when the market had hardly developed), through large rigid tenders to a range of vehicles, all of which complement each other and contribute to the single goal of buying carbon credits.

This strategy of diversifying procurement through different paths to market may be considered for the post-2012 period. There is even greater opacity in the long-term market for carbon credits, where few ERPAs have been signed and none of them are in the public domain.

While this presents a challenge to all those considering acquiring carbon credits beyond 2012, the ability and experience built by the private sector over the last five years is considerable and the first question European governments may ask is whether there remains a role for public procurement in their national climate change policy framework. The implication is that taxpayer's money would be spent investing in carbon reduction projects abroad, and in competition with the private sector, including entities from its domestic private sector.

If the decision is made to go ahead with a procurement programme beyond 2012, an important factor now is the uncertainty and opacity in the post-2012 credit market. Considering the advantages and disadvantages of the various procurement techniques employed by European governments, any sovereign buyer of post-2012 credits may:

- Establish its strategy and act early to secure volumes at advantageous prices
- Consider using a range of tools to access the market, including some or all of, but not limited to, the following:
  - tenders,
  - direct investment,
  - cooperation with intermediaries,
  - investment in closed and multilateral funds, etc.
- Draw in credits from different project types, including possibly CCS and land use, land use change and forestry. However, it is also useful to build expertise in a range of a few project types / methodologies, those with high issuance rates compared to Project Design Document volume.
- Focus on a narrow range of countries, possibly with local presence, as the local conditions are key to how a project runs.
- Whatever other geographical or technological criteria, consider credits from a few large projects (with relatively higher risk as a result) to increase volume at low cost.
- Spread its investment across various countries and at a range of prices.
- Consider some investment in CERs offered on the secondary market.

8. Conclusions

In the context of European and Dutch greenhouse gas reduction target there is a need for more quantified research into the potential and cost for carbon credits after 2012. This report aims to shed more light on this issue.

The main conclusion of this report is that the technical potential for greenhouse gas reduction options up to 20 €/tCO_2-eq abated in non-Annex I countries is likely to be larger than 4 GtCO_2-eq/yr in 2020. If avoided deforestation is excluded this potential is estimated to be approximately 3 Gt/yr. This study has also made clear that the extent to which this potential can be harnessed by CDM strongly depends on future eligibility decisions, notably for avoided deforestation, the application of the additionality criterion, and to a lesser extent the success of programmatic CDM and adoption rate of technologies. Taking these uncertainties into account we estimate the market potential for CDM projects at 1.6 - 3.2 GtCO_2-eq/yr at costs up to 20 €/tCO_2-eq in 2020. Demand for carbon credits could be in the same order of magnitude, depending on the post-2012 negotiations and domestic reductions in countries with commitments. In addition to CDM, Joint Implementation (JI) projects in Russia and Ukraine and 'hot air' may play a significant role in post-2012 carbon markets.

The potential estimates involve a degree of uncertainty. The main limitation of our approach is that it does not cover all abatement options in all countries. In addition the abatement cost of most mitigation options are highly sensitive to energy prices, which makes any estimation uncertain. Taking these uncertainties into account, the results are considered a conservative estimate as shown by a rough comparison with results from other studies, and the fact that data have been affirmed by the expert reviewers in China, India, Brazil and Senegal. The estimates for the market potential of CDM options should be seen as an attempt to give a semi-quantitative analysis of what the impact of several uncertainties on the potential for CDM project may be, rather than an exhaustive study into the market potential.

Important technologies that could play an increasing role are LULUCF and energy efficiency in the public sector. Eligibility of avoided deforestation is to be discussed in the international climate negotiation, and an outcome may be that it can better be covered by a mechanism different from the CDM. Success of energy efficiency projects in the buildings and transport sector depends to a large extent on developments in programmatic CDM. We estimate that programmatic CDM will increase the likelihood of implementation of abatement technologies, in particular energy efficiency that together could amount to between 1 and 1.6 GtCO_2-eq/yr.

Projects registered up to September 2007 are likely to generate approximately 1 billion CERs between 2013 and 2020. Point Carbon estimated approximately 450 MtCO_2-eq/yr on average in the same period from existing and upcoming projects up to 2012. Fugitive emission reduction, renewable energy and energy efficiency are expected to increase in importance, while industrial gas abatement reduces its share in the CER supply.

A qualitative assessment of possible developments regarding post-2012 climate negotiations shows that the shape, scope and size of the carbon market is highly uncertain. Demand for credits depends on the new commitments Annex I (and possibly also some non-Annex I) countries are willing to take on, and whether the full regime will remain based on a cap-and-trade principle. Two post-2012 climate scenarios were examined: A) continuation of the current situation with no progress on expanding the list of countries in Annex B (20% reduction target for the EU), and B) a rapid roll-out of targets to a list including the world's two biggest emitters, US and China, in addition to 30% reduction for the EU. Compared to emissions in 2005, the EU-27 needs further reductions of 0.5 to 1.0 GtCO_2-eq/yr in 2020 to achieve the target of 20 to

30% emissions below 1990 levels and may consider using carbon credits to assist in achieving this target. Demand for GHG reduction by the US in Scenario B could be even larger than that. This qualitative assessment, therefore, yields that the demand for carbon credits may be in the same range as the CDM market potential of 1.6 to 3.2 GtCO_2-eq/yr in 2020. Banked AAUs from the 1st Kyoto commitment period (up to 5 GtCO_2-eq) and excess AAUs for China in Scenario B, however, could also cover a significant part of demand for carbon credits between 2013 and 2020.

The level of integration of different carbon markets remains uncertain. It is possible that the carbon market will remain fragmented into different types of credits, including EUAs, CERs, and AAUs. It is also possible that most of the market corresponds to a single price for one tonne of CO_2-eq, thus being fully integrated. Linking between regional markets can differ in nature, from direct links where credits are fully fungible across more than one system to indirect links, where for example separate systems all draw on a single pool of project-based credits. It is even conceivable (but not considered likely) that voluntary credits gain an official status, which will result in competition between VERs and CERs for several technologies.

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Appendix A Non-CO_2 GHG update for TETRIS

The vast majority of mitigation options included in the original TETRIS database are focused on CO_2 mitigation options only. This annex explains the process of including other greenhouse gasses into the database on the basis of which MAC curves for the non-Annex I region are constructed (see Chapter 3).

General appreciation of the USEPA study

The US Environmental Protection Agency (USEPA) report *Global Mitigation of Non-CO_2 Greenhouse Gases* (USEPA, 2006) is used as a basis for inclusion of non-CO_2 mitigation options into the TETRIS database. The report includes a global inventory of anthropogenic nonCO_2 gases that serve as baselines for assessment of mitigation options and a breakdown by countries with the most available mitigation potential. What follows is a brief description of the study's characteristics with an emphasis on the most important issues for integration of results from various sources into one MAC.

Information sources and estimates of missing information

Several of the information sources used in this study relating to non-CO_2 mitigation potential and costs were already used for CO_2 mitigation potential in TETRIS; developing countries emissions estimates are taken from the latest *National Communications,* in *Asia Least-Cost Greenhouse Gas Abatement Strategy* (ALGAS) (Asian Development Bank, 1998), or in a country-specific report. When the emissions data from these references did not cover the entire historical or projected period from 1990 to 2020, the following approach was used: first, emissions growth rates were estimated based on IPCC Tier 1 estimates for the country for 1990 through 2000. The growth rates were applied to reported inventories since 1990 and used to estimate the remaining years through 2000. Next, growth-rate projections were applied to source-specific drivers for each country, using the estimate for 2000 as the base year to obtain projections to 2020. For example, a country's emissions in the oil sector are correlated closely with oil production trends, and hence the projected increases of oil production are the base for the estimated emissions from this source. For landfill methane emissions, the increase in municipal solid waste and change in waste management practices are taken into account when formulating emission projections from this source. When no emissions data were available or when the data were insufficient, the USEPA developed emissions estimates, projections, or both, using the default methodology presented in the *1996 Revised IPCC Guidelines* and the *IPCC Good Practice Guidance 2000*.

Information resolution

The abatement potential for each source is then estimated considering applicable abatement technologies. The number of mitigation technologies varies, from three for coal-based emissions of methane to 118 mitigation options for fugitive methane emissions from the production and consumption of natural gas. Due to such variations, the technical mitigation potential is not always presented per country-technology as in the original TETRIS database, but per country (or region)-emission source and is a figure that aggregates all the potential from technologies applicable to the particular emission source in the individual country/region. Where the number of mitigation technologies applicable is small, they are of course presented in the standard country-technology format.

Although the scope of the study was global, it does include a breakdown of individual countries with the biggest mitigation potentials. Countries with smaller potentials were grouped into geographical regions (e.g. the Middle East, Africa), which causes a variation in the database's geographical resolution. While this does not affect the accuracy of the technical mitigation potentials estimate, it does restrict the cost-comparison of different abatement options between countries other then the most important ones (China, India, Brazil, Mexico).

A bigger limitation of the study is the resolution of costing of the abatement options, which are presented in cost-classes starting from 0 to 60 €/tCO_2-eq by incremental steps of € 15. Sectors where many abatement options apply are therefore grouped into cost-classes and not presented at their breakeven cost. This approach gives the MAC curves a very step-wise form. Furthermore, it often does not offer a good comparison of differences in costs between abatement options considerably. For example, the HFC-23 abatement options that have a breakeven cost of less the 0.5 €/tCO_2-eq are presented in the 15€ reductions categories, which is a substantial overestimate of the actual abatement costs. For this reason, where possible, data was read directly from the MAC curves (not presented for every country/region) which are much more accurate then the data presented in tables (available for all countries/regions) and other sources were consulted.

Accounting for realised reductions
Baseline projections represent business-as-usual scenarios, which include currently achieved reductions but no climate policies which would facilitate and generate adoption of mitigation options. However, future mitigation actions are included if either a well-established program or an international sector agreement is in place. Thus they do include voluntary and non climate-based policies that indirectly reduce greenhouse gases. For consistency, if a country's reported projections include planned climate mitigation efforts, the reductions from those efforts were added back into the emissions projections (USEPA, 2006). This means that the potential that will be realized in the first commitment period is not subtracted from the total mitigation potential to see what is left for a second commitment period. The study however does include the already implemented HFC-23 abatement projects and deducts them from the baseline of HCFC-22 production emissions.

Accounting for learning effects
The study has a static approach and thus does not account for the technological change in such option characteristics as availability, reduction efficiency, applicability, and costs. For example, the same sets of options are applied in 2010 and 2020 and an option's parameters are not changed over its lifetime. This current limitation likely underestimates abatement potential because technologies generally improve over time and costs fall. The introduction of a dynamic approach to assessing regional abatement potentials requires additional assumptions about rates of technological progress and better baseline projections, that, once incorporated into this analysis, will yield a better representation of how MACs change over space and time (EPA, 2006). However, for the energy and waste sectors, a sensitivity analysis is performed that illustrates the effect of technical change over time. Unfortunately not enough information is provided to extend such an exercise across all sectors.

Transactions costs
The study does not include transaction costs of any kind. However, as these options are in the realm of non-CO_2 gases, the transaction cost as applied in the TETRIS approach will be low, i.e. 0.2 €/tCO_2-eq, which can be called negligible.

Indirect reductions
The study does not include indirect reductions.

Discount and tax rates
The results for 2010 and 2020 use the base energy price, a 10% discount rate, and a 40% tax rate.

Accounting for market, institutional and other barriers
The MACs are determined by the abatement potential of given economically feasible mitigation options at a given breakeven price, thus representing the technical potential of non-CO_2 reduction options. Market and other barriers were not considered which is reflected in the existence of no-regret options that have not yet been implemented although they make the most economic sense. The following sections are a short description of the emission sources of non-CO_2 greenhouse gasses and abatement technologies included in the study.

Methane from the energy sector
Coal mining emissions come from ventilation and degasification systems of (underground) coal mines. The abatement technologies included are degasification, enhanced degasification, oxidation of ventilated air methane.

In natural gas systems CH_4 emissions occur from normal operations in each of the four segments of the natural gas industry (production, processing, transport, storage and distribution). Equipment/pipeline leaks and venting activities are the primary sources of CH_4 emissions in the natural gas sector (USEPA, 1996). Abatement options for the natural gas sector generally fall into three categories: equipment changes/upgrades, changes in operational practices, and direct inspection and maintenance. Many abatement options are applicable across all four segments of the natural gas system. Options range from upgrading compressors and pipes to enhancing inspection and detection techniques (descriptions of options in EPA, 2006, Annex C, Table C-8).

Oil sector CH_4 emissions are associated with crude oil production, transportation, and refining operations. These oil production segments release CH_4 into the atmosphere as fugitive emissions, emissions from operational upsets, and emissions from fuel combustion (USEPA, 2004). Three abatement options are discussed for the oil sector: flaring, direct use, and reinjection of gas into oil fields.

Waste sector
Landfill emissions: CH_4 makes up approximately 50% of landfill gases, with the remaining 50% being CO_2 mixed with small quantities of other gases. If landfill CH_4 is not collected, it will escape to the atmosphere. Abatement options include the capture of CH_4 for flaring or energy production and enhanced waste management practices to reduce waste disposal at landfills (such as recycling-and-reuse programs). CH_4 flaring or recovery for energy are the most comon approaches and are the focus of this report.

N_2O abatement from production of nitric and adipic acid
N_2O is emitted in the waste gas stream (USEPA, 2001). Nitric acid is an inorganic compound typically used to make synthetic commercial fertiliser and in the production of adipic acid, explosives, metal etching and in the processing of ferrous metals. Adipic acid is a white crystalline solid used primarily as a component in the production of nylon (nylon-6-6). The two abatement options considered are catalytic reduction for N_2O emissions from nitric acid and thermal destruction for adipic acid. It is estimated that there are no 'no-regret' options for N_2O nitric or adipic acid production. At a breakeven price of € 15 per tCO_2-eq, the percentage abatement is 89% for nitric acid and 96% for adipic acid, reflecting the relatively high technical potential and low abatement cost for options in these industrial processes.

HFCs from refrigeration and air conditioning
The costs and emissions reduction potential of eight practice and technology emissions mitigation options are included: (1) leak repair for large equipment, (2) refrigerant recovery and recycling from small equipment, (3) distributed system, (4) HFC secondary loop, (5) ammonia secondary loop, (6) enhanced HFC-134a systems in motor vehicle air conditioning (MVACs), (7) HFC-15_2a systems in MVACs, and (8) CO_2 systems in MVACs.

PFC emissions from aluminium production

The declining global emissions levels through 2010 reflect the successful adoption of the International Aluminum Institute (IAI) emissions reduction goals through both retrofits and a continued shift of production towards less polluting technologies. Within this context the study considers a 'no-action baseline scenario', in which it is assumed that aluminum producers will take no retrofit actions to reduce their emissions below the levels of the late 1990s; and a 'technology-adoption scenario' that includes the targets of the IAI into the baseline calculations. To produce a conservative estimate of abatement potentials (and hence options for earning CERs), we will only take into account the projections of the 'technology-adoption' scenario. The retrofitting options are numerous and are not assessed separately but grouped according to abatement cost.

HFC23 from HFCF-22 production

The USEPA study was not the only report used for estimates of the abatement potential of HFC-23 from HCFC-22 production. The reason is the striking difference with another elaborate study by the Oeko Institut and ZEW (Cames et al, 2007). They estimate the potential for HFC destruction from existing plants in 2020 at 102 $MtCO_2$-eq, and the potential for new plants (built after 2004) also at 102 $MtCO_2$-eq. In 2015 the figures are 102 and 93 $MtCO_2$-eq respectively. This is much larger than any of the estimates in USEPA (2006), which gives an estimate of approximately 50- 100 $MtCO_2$-eq, depending on the scenario. The two studies differ in the projected growth of HCFC-22 production and we find that a combination of information inputs from both leads to a most up-to-date and realistic abatement potential.

The USEPA study considers two scenarios for HCFC-22 production: the 'no action baseline' and the 'technology adoption baseline', the difference between the two being the consideration of CDM projects for HFC-23 destruction that were identifiable at the time of writing (mid 2006). Both scenarios differentiate between feedstock and non-feedstock production of HCFC-22, however, in all cases the production projections of HCFC-22 was calculated in the same way (USEPA, 2006b). To derive 2005 and 2010 production, the 2003 production data from IPCC/TEAP Special Report on Ozone and Climate (IPCC/TEAP, 2005), was grown linearly to reach the 2003 SROC-reported production capacity and production for 2015 was estimated by growing the 2010 production at the expected rate of growth of GDP. After 2015, non-feedstock production was assumed to decrease linearly so that complete phase-out occurred by 2040, while feedstock production continues indefinitely.

Regardless of the rate of abatement technology adoption in non-Annex 1 countries (0% or 50%) there is still a large discrepancy between USEPA's and Oeko Institut and ZEW's estimate of abatement potential of HFC-23. The latter also bases its estimates on abatement potential on the IPCC/TEAP Special Report on Ozone and Climate (IPCC/TEAP 2005), and goes on to include production levels reported by the Parties to the Montreal Protocol to UNEP in accordance with Article 7 of the Montreal Protocol (UNEP 2001/2002/2003/2004) and information provided by the experts interviewed. The production is expected to continue to grow continuously until 2015 and the dispersive use of HCFCs is assumed to only be phased out between 2030 and 2040. Based on this information sources, Oeko Institut and ZEW estimate HFC-23 emissions from HCFC-22 production of around 102 $MtCO_2$-eq by 2020 from existing plants and another 102 $MtCO_2$-eq from new plants by the same date. As mentioned, the report assumes HCHC-22 production to peak only between 2020 and 2030, while the EPA report expects the peak to be reached in 2015 after which a decline in HCFC-23 production for dispersive uses will cause a decline in HFC-23 emissions, as foreseen under the Montreal protocol under which developing countries would start phasing out HCFC for non-feedstock uses as well. In fact, at the last meeting of parties to the Montreal protocol, it was agreed that even developing countries would freeze their production and consumption at an average of 2009 and 2010 levels by 2013 (three years earlier then originally planned) with a gradual phase-out of HCFC gases from 2016 through 2030 (Point Carbon, 2007a). In light of the recent developments of the Montreal protocol and the still uncertain additionality of new HCFC-22 plants, we view the Oeko Institut and ZEW's projections of peak production by 2030 as an overestimate.

Considering all of the above we decided to use the Oeko Institut and ZEW's estimate of total HFC-23 mitigation potential of 149 $MtCO_2$-eq by 2010 (102 from existing plants and 47 from new ones) as the basis for our calculation. To arrive at an estimate for 2020, we make a distinction between the production of HCFC-22 for feedstock and non-feedstock uses. Given that about 40% of total global requirement for HCFC-22 would be for feedstock (IPCC/TEAP 2005), we calculate that 59.6 $MtCO_2$-eq continues to be produced throughout the period under consideration for feedstock uses, while the remaining 89.4 $MtCO_2$-eq is linearly reduced to reach zero by 2030, thereby arriving at a figure of another 59.6 $MtCO_2$-eq remaining from non-feedstock uses by 2020. Our final figure is therefore an abatement potential of HFC-23 from HCFC-22 production of 119.2 $MtCO_2$-eq in 2020, of which 17 Mt from new to build plant. It must be noted that 70 $MtCO_2$-eq have already been mobilised in registered CDM projects (UNEP/Risø, 2007). By downsizing Oeko Institut and ZEW's estimate of technical potential with the Montreal protocol restrictions, we have arrived to an abatement potential estimate very similar to US EPA's. Finally, all these projections are subject to considerable uncertainties and sensitivities. Future production levels, emission rates and abatement levels are particularly uncertain, making a conservative interpretation of the potential preferable.

SF6 from industrial processes

Electrical systems: As infrastructure expands to meet the demands of growing populations and economies, emissions are estimated to grow at a rate proportional to country- or region-specific net electricity consumption (USEIA, 2002). This growth drives global emissions growth, and by 2020, Latin America, South and East Asia, the Middle East, Africa, and China/CPA are expected to account for 63% of total emissions, versus approximately 10% in 1990. The emissions from developing countries are the same under both 'no-action' and the 'technology adoption' scenarios, cause no voluntary reductions are expected from those countries. The abatement technologies included can be categorized as SP6 recycling & leakage detection and repair.

Magnesium production: Under the Technology-Adoption Baseline scenario, it is assumed that Mg producers and processors outside of China will introduce technologies and practices aimed at reducing SF_6 emissions. Under this scenario, International Magnesium Association (IMA) members, who account for 80% of the global Mg industry outside of China (IMA, 2003), will meet a target of eliminating the use of SF_6 by 2011. By the end of 2010, in accordance with the IMA goal, all countries except China are assumed to have eliminated the use of SF_6 from Mg production and casting operations. For China, it is assumed that some primary production and all casting facilities will use SF_6 to produce high-quality magnesium and products for the world market. Because Chinese producers and processors are not IMA members and have not committed to the IMA emissions reduction goal, their SF_6 use is assumed to continue through 2020. Consequently, from 2010 through 2020, the increase in global emissions from 4 to 5 $MtCO_2$eq will be driven entirely by China. The abatement options considered can be grouped as 'replacement with alternative cover gases' (EPA, 2006).

Appendix B CCS potential methodology

Introduction

This section of the report describes the approach taken to the development of the marginal abatement curves for carbon capture and storage for the year 2020. This section includes information about the geographical scope, the sources covered, the way in which abatement and costs were calculated and the development of a scenario to downscale the overall potential for CCS into a realistic figure for delivery in 2020.

Scope - Sectors and Technologies

Ecofys' expert[31] opinion was used to identify the key sectors to be covered in this assessment. Both power plants and some parts of industry may implement CCS in the period 2012-2020.

In choosing sectors the advice was taken that between 2015 - 2020 and upwards industry may have good opportunities to capture and store CO_2 from pure sources such as production processes for ammonia, hydrogen, ethylene oxide, LNG and gas processing. In a later stage the large and heavy industries may introduce CCS, specifically the iron and steel, refineries and cement industry. Newly built coal and natural gas power plants will also constitute an important area of CCS application from 2015 onwards. CCS also enables the centralised production of hydrogen for decentralised use, but no substantial market penetration is expected before 2020.

Therefore, for the period 2013-2020 only point sources of pure CO_2 (sector name: 'Industry') and newly built power plants (sector name: 'Power') are relevant.

'Existing power plants' and 'other industry' were not taken into account. The reasoning is that it is highly unlikely (in our experts' opinion) those sectors will implement CCS before 2020. The likely reasons for this exclusion include the extra costs involved, technical difficulties and other uncertainties.

The point sources of pure CO_2 that were chosen in particular were:

- Ammonia: ammonia production results in two CO_2 streams, one of 100% purity and one of 8% purity (which is flue gas from the burners).
- Ethanol production: CO_2 purity varies and can range from 90% in some cases to as high as 98-99% for dry biomass sources. Therefore ethanol is included as a nearly pure source
- Ethylene oxide production
- Hydrogen production**:** Not all hydrogen plants produce 100% pure CO_2. Plants that are based on steam methane reforming technology, and on coal or heavy residues can produce 100% pure CO_2 directly, but they do not always do so.

Newly build power plants include:

- Natural-gas-fired plants
- Coal-fired plants

The calculations were made independent of whether pre-combustion, post combustion or oxyfuel CCS technology was used. It was considered inappropriate at this stage to attempt to anticipate the CCS technology used. Instead, all potential was assessed and included under the broader technology heading 'CCS'.

[31] Chris Hendricks, discussion 2007.

Certain key sources that have not been included, but may have some relevance to delivery before 2020 include:

- Natural gas processing: These have not been included because of a lack of data at this stage. Publicly available information in the IEA database on natural gas processing relates only to the UK and Canada and there are no other sound data sources available at this stage. As a result of the omission of this source, estimates for CCS could be revised upwards slightly.
- Cement plants: As indicated above, expert opinion indicates that cement plants are not likely to be a significant source for CCS projects before 2020. However, cement plants represent a considerable proportion of CO_2 emissions in the non-Annex I countries studies so a small number of projects may occur before 2020, possibly stimulated and supported by private sector investment. Data on cement plant emissions are available, however, have not been investigated here due to the likely slower uptake as compared to pure sources in the period 2015-2020. As a result of the omission of this source, estimates for CCS could be further revised up slightly.

Costs of CCS

In determining abatement costs, the key source for storage potential data was Hendriks et al (2004) and information on the costs of capture came from in-house expertise[31]. All costs were calculated in euros and then converted to dollars using an exchange rate of 1.2 dollars per euro.

Capture costs came from Ecofys' in-house expert assessment and were estimated at:

- Point sources pure CO_2: 5 €/ton
- Newly built power plants: 30-40 €/ton
- Existing power plants: 50-60 €/ton
- Industry: 40-50 €/ton

The data for power plants were broken down further into newly built coal or gas-fired plants (independent of pre- or post combustion technology):

- 40 €/ton CO2 for natural gas fired plants
- 30 €/ton for capture from coal fired plants.

These cost figures correspond to what is given in the IPCC report on carbon capture and storage (IPCC, 2005; p.150-157). The lower intensity of CO_2 in gas-fired units tends to increase the capture costs per tonne of CO_2, but the capture cost per kWh output is generally somewhat lower for NG-plants than for coal-fired plants.

Cost calculations for storage and transport were calculated based on existing assessments of storage capacity in different regions of the world.

In calculating available storage potential, it was assumed that before 2020 no CCS installations will have been built. Therefore only the cheapest transport and storage option in each world region were used in the calculations of the costs in 2020. However, storage will need to be available for the entire 20-30 year plant lifetime of any new facilities when plans are made for investment. This means that as CCS becomes more established, and with time, storage limitations will become more important in investment decisions and may begin to cost more.

Abatement potential

Abatement potential for point sources of pure CO_2 were calculated based on the CO_2 emissions and sectoral growth factors from the International Energy Agency.

Abatement potential for newly build power plants were calculated based on CO_2 emissions which were based on new and replaced electricity generation and sectoral growth factors from the World energy Outlook and emissions factors (separately for coal and gas)

Data for the Ukraine was based on CO_2 emissions calculated using new electricity generation estimated on the data from IEA Energy Balances (2005), growth factors from IEA GHG CO_2 Emissions Database 2006 and emission factors because the data was not available from the WEO 2006, the source used for the other countries and regions.

The potential for abatement is given for the year 2020 in terms of $MtCO_2$/year. Theoretically figures could have been provided for the year 2016, mid-way between 2013 and 2020 in order to represent the overall period 2013-2020. However, the year 2020 is of the greatest use in the case of CCS because of the slow implementation in the period leading up to 2020.

Methodology applied to calculate the abatement potential of point sources pure CO_2

Taking into account the country and region division as indicated in the Table 1, the IEA database was filtered to extract the relevant records on the amount of CO_2 emission in respect to the relevant sources.

The IEA database provides detailed emissions per installation in each country. These emissions were summed at a country or regional level and converted to more appropriate unit i.e. $MtCO_2$. Some data was provided at the regional level, exclusive of data for countries specified individual (i.e. data for the rest of Latin America region does not include data for Brazil and Mexico).

Emissions data was provided for certain years, as follows: ammonia (2000), ethanol (2003), ethylene oxide and hydrogen (both 1999). Specific sectoral growth rates were used to estimate the size of the emission in the years 2013-2020. These growth rates were differentiated in relation to country/region, technology and years (per decennium 2000-2010 and 2010-2020). Growth rates for ammonia, ethylene oxide and hydrogen were taken from the IEA GHG database (2006). An annual growth rate of 2.5% was used for ethanol, as an average of the potential growth rate for the ethanol sector provided in other sources (Hendriks et al, 2002).

The formula used to calculate abatement potential for a certain year based on CO_2 emissions in a given year and the growth rate(s):

$$AP = P*(1+G)^{(Yx - Yb)}$$

AP - Abatement potential in the relevant year for which we want to calculate the data (Yx)
P - CO_2 emission in the base year as the source indicated (Yb)
G - Growth rate
Yb - base year, from which the calculation starts, year from which the data gathered from the database originates
Yx - a year we want to make the calculation for

In case where the growth rate was not equal in the two decenniums (2000-2010 and 2010-2020) first the abatement potential up to 2010 was calculated. Then the 2010 figure was used for further calculation of the AP in 2020.

Methodology applied to calculate the abatement potential of newly build power plants

Based on the data on electricity generation from coal and gas for the year 2004 and 2015 and their growth rates in the two decenniums (2000-2010 and 2010-2020) we were able to calculate the total annual electricity generation in each year from 2013 till 2020 for coal and gas separately. The same formula was used as given in the previous section using electricity generation, instead of CO_2 emissions as the initial input.

Using the total annual electricity generation, electricity generation for the newly build power plants only was extracted by subtracting data from the previous year. As the new capacities consists of both new and replaced power plants (that are shut down and replaced by new power plants) we had to also calculate the replaced capacities. Together with the new power plants that are built to cover increases of power demand they form the total amount of new capacity. Since the lifetime of coal and gas plants is assumed to be 30 years, each year 1/30 of the total capacity in that year is replaced. This figure was used as the basis as estimates for the replaced capacities. So the sum of new and replaced capacities for coal and gas gave the total information on the new capacities powered by these two fuels.

In the next stage the electricity generation for the total of new capacity was multiplied by a country/region and fuel specific emission factor resulting in the abatement potential for a given year. Calculations were made for the countries and regions as stated in Table B.1.

In order to calculate the annual emissions abatement potential of CCS in new built power plants in 2020, all newly built capacity and replaced capacity from the years 2015-2020 was added together. In the year 2020 emissions reductions from CCS would be technically possible from all these installations. See section on penetration rates later in this Annex for the explanation on how penetration of CCS into these new capacity was calculated from 2015-2020.

Geographical Scope

The marginal abatement cost curve built for CCS covered:

- Annex I countries: Russia and Ukraine.
- Non-annex I countries.[32]

The key data sources used for the study used slightly different country divisions. As a result, the data for point sources of pure CO_2 uses a different division in some cases than that for newly built power plants. The divisions given in the original data sources are shown in the tables below. Where additional decisions were made about categories, these are also indicated.

Geographical regions for cost elements

In determining abatement costs, the key source for storage potential data was Hendriks et al (2004). The relevant divisions for countries in this study are shown below.

[32] Dependent on data availability.

Table B.1 *Geographical regions used for storage costs*

Country	**Region (Hendriks et al. 2004)**[33]
Russia	Former S.U.
Ukraine	Former S.U.
China	East Asia
India	South Asia
Brazil	South America
South Africa	South Africa
Iran	Middle East
Mexico	Central America
Indonesia	S-E Asia
Republic of Korea	East. Asia
Argentina	South America

The Use of Scenarios

The theoretical potential for CCS explored using the data above results in a complete assessment of all of the sources of CO_2 from these industrial and power processes in the target countries. However, it is unlikely that all of the CO_2 calculated will actually be captured in 2020.

Two main considerations need to be taken into account. Firstly, the capture efficiency may not be 100%, even if an attempt is made to full capture the gases. Secondly, the uptake of CCS is not likely to represent the full amount of CO_2 available. In order to produce a more likely estimate a scenario has been developed based upon work for the UNFCCC (Hendriks, 2007). In this document a model to indicate CCS development in different regions of the world between today and 2030 was developed. The scenario aims to develop a picture of CCS that is ambitious but realistic not only at the global level, but also at the regional level.

The scenario includes the basic assumption that there is an 85% capture efficiency, and proceeds from the starting point that in 2030 50% of new power plants, built from 2015, will operate carbon capture and storage and 70% of pure sources of CO_2 from industry will be captured and stored. Besides power plants some industry may also implement CCS from 2015 onwards. Industry options primarily relate to pure sources of CO_2. At a later stage large and heavy industries may also introduce CCS, specifically the iron and steel, refineries and cement industry.

To come to an ambitious and realistic scenario it is necessary to understand what may determine maximum levels and maximum penetration rates of CCS. We distinguish the following crucial elements:

- pace of implementation and time-scale of large-scale introduction of CCS,
- availability of sufficient storage capacity,
- availability of technology;,
- non-technical barriers, and
- financial incentives.

Is the pace of technology development sufficient?

Before large-scale implementation of CCS can be done, technology development is still required, mainly in the capture part of the CCS chain. It is envisaged that at least two generations of pilot and demonstration plants are required. As demonstration plants need often

[33] Relevant for the storage potential.

considerable time this will affect the timing of full-scale commercial implementation. On the other hand, no real technical showstoppers have yet been identified. Based on current development, and the need for demonstration of the technology, large-scale implementation could probably be realised from 2020 onwards.

Due to the forecasted increasing demand of power and the relatively high age of the stock, considerable amounts of power capacity will be constructed over the next decades. To be able to apply CCS after 2020 on plants that were built before the technology was ready (i.e. between 2015-2020), it is possible to apply the 'capture-ready' approach, i.e. plant built any time after 2015 should be built in a way that makes retrofitting relatively easy. In principle, retrofitting of existing stock is also possible, but often (far) more expensive.

Is there enough storage capacity?

In a first analysis based on the current knowledge of storage potential worldwide (composed from current knowledge), the likely demand from CCS by 2030, and certainly by 2020, is small compared to the storage capacity available worldwide. Further issues may arise after 2020, and particularly in relation to the regional distribution of storage sites within regions, correlated to demand.

Is the technology available?

The CCS technology can be applied worldwide and transfer of the capture technology should be possible. We expect that the technology for large-scale units can be available for implementation from 2015. However, as there is still the need for demonstration plants and cost reduction, commercial implementation will only take off after 2020. This is especially the case for capture from power plants. In the industry, there are also some ‘low hanging fruits’ which might be applied in an earlier stage. Examples are relatively pure sources of CO_2 from gas processing, LNG production, ethylene oxide production, hydrogen and ammonia production (as described earlier).

Are there non-technical barriers?

Legal implications and public attitude may be important with respect to carbon capture and storage. Based on the current developments in legal and regulatory issues it is not yet sure the pace is quick enough. Especially this might be the case where it concerns the implementation of larger-scale demonstration facilities. Open issues are e.g. the classification of CO_2, long-term liability, and cross boundary movement of CO_2.

Recently some substantial steps have been made to remove legal barriers in many parts of the world. A further important aspect is the need to develop an adequate and advanced set of monitoring reporting and verification protocols. Despite the increased attention to the subject in the media in the last year, the majority of the public is still quite unaware of this option. There may be a need to increase communication with the public on this technique to have a dialogue about public acceptance of carbon capture and storage.

Financial incentives

Strong, long-term and reliable policies are therefore a prerequisite, as CCS requires large upfront investment which should be recovered over a longer period. Investment will only be made, when substantial confidence is present in the market. Emission trading schemes and the

Kyoto instruments Joint Implementation and Clean Development Mechanism[34] are currently seen as the most important instruments to finance CCS activities, especially in the commercial phase of the implementation. Alternatively, CCS could be made mandatory, taking away all uncertainties out of the market, although for the purposes of this study, such an approach would remove CCS as a source of post-2012 carbon credits, because such projects would no longer be additional. Mandatory CCS in non-Annex I countries before 2020 is also very unlikely to be politically feasible.

A scenario for the implementation of CCS post-2012

As described earlier, a scenario has been developed on the basis of the analysis given above. This scenario assumes 70% of pure sources and 50% of newly built plants, from 2015, will use CCS by 2030. The scenario also assumes that only newly built power stations will be equipped with CCS. For OECD countries, specifically Europe, it is expected that in the period towards 2020 CCS will be implemented for a limited set of plants, or will be made capture-ready to some extent.

The expectation is that in the starting phase CCS will mainly be applied in OECD countries, especially those countries with good access to (depleted) hydrocarbon reservoirs or possibly suitable aquifers. After 2020, the rest of the world will gradually implement CCS, mainly applied at coal-fired stations. CCS may also be applied to biomass-fired plants, resulting in a net sink of CO_2. Implementation of CCS and its magnitude will be steered mainly by political willingness to reduce greenhouse gas emissions substantially and the availability of alternative solutions that can contribute significantly in the timeframe up to 2030.

The figures in Table B.2 show the interim levels of application of CCS in newly built power plants across different regions of the world. The figures for 2015-2020 have been applied to the abatement potentials in the MAC curve to provide an analysis of potential for the non-Annex I countries. It was assumed that the potentials in 2020 would be achieved linearly from 2015 to 2020 and the average potential penetration rate for the relevant world region was then applied to the data set of new or replaced capacity between 2015-2020.

Table B.2 *Implementation scenario for CCS in new coal and natural gas-fired power plants*

	2015		2020		2025		2030	
% of new capacity	coal	NG	coal	NG	coal	NG	coal	NG
USA and Canada	4	0	13	12	56	23	100	44
Other OECD	30	0	56	12	92	23	100	44
Latin America	0	0	5	8	21	18	42	26
Russia	0	0	12	12	56	34	83	39
China	0	0	6	6	24	12	56	17
India	0	0	6	6	24	12	56	17
Other	0	0	7	9	33	16	59	30
Total	**2**	**0**	**10**	**10**	**37**	**20**	**70**	**35**

The two graphs below show how the percentage penetration rate in new natural gas and in new coal plants change with time, going from 2015 through to 2030. E.g. for ‘other OECD’ countries, in 2015 30% of the new built coal-based capacity is equipped with CCS, and the plants that are built in 2030 are all include CCS. Note that the figures do *not* indicate the overall penetration rate of all installed capacity per region, but refer to new built plants only.

[34] The Clean Development Mechanism might be a vehicle to speed up the transfer of technology to developing countries. It should be noted that CCS for CDM is currently not yet approved by the UNFCCC. Nevertheless, it is expected that this will be the case far before 2020, assuming that the CDM instrument is still in place.

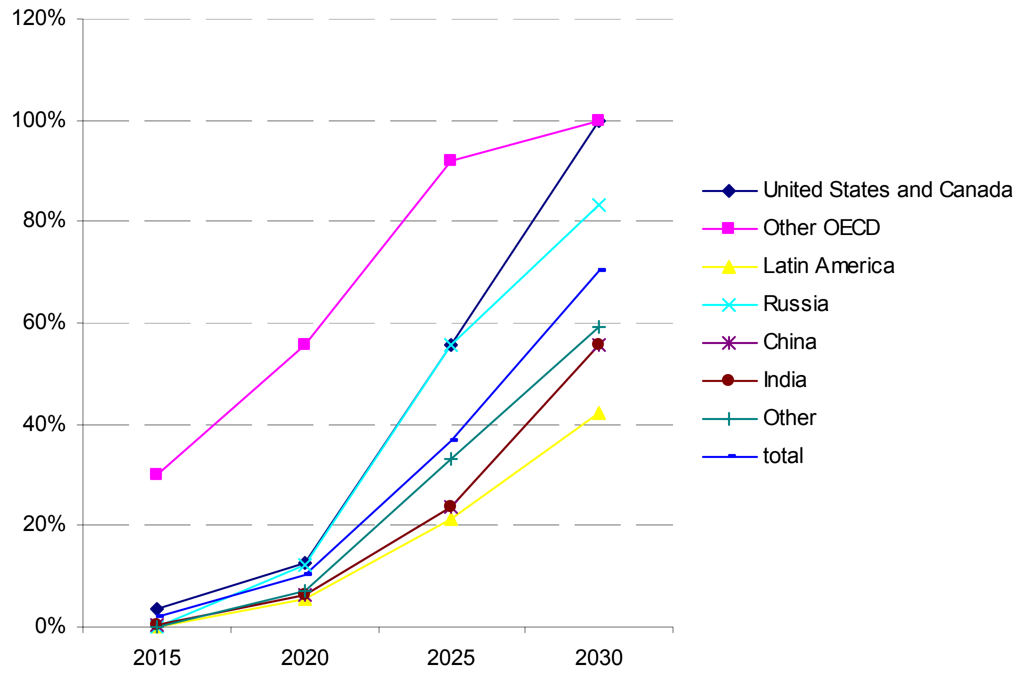

Figure B.1 *The penetration rate of CCS (% CCS of new coal capacity built per year)*

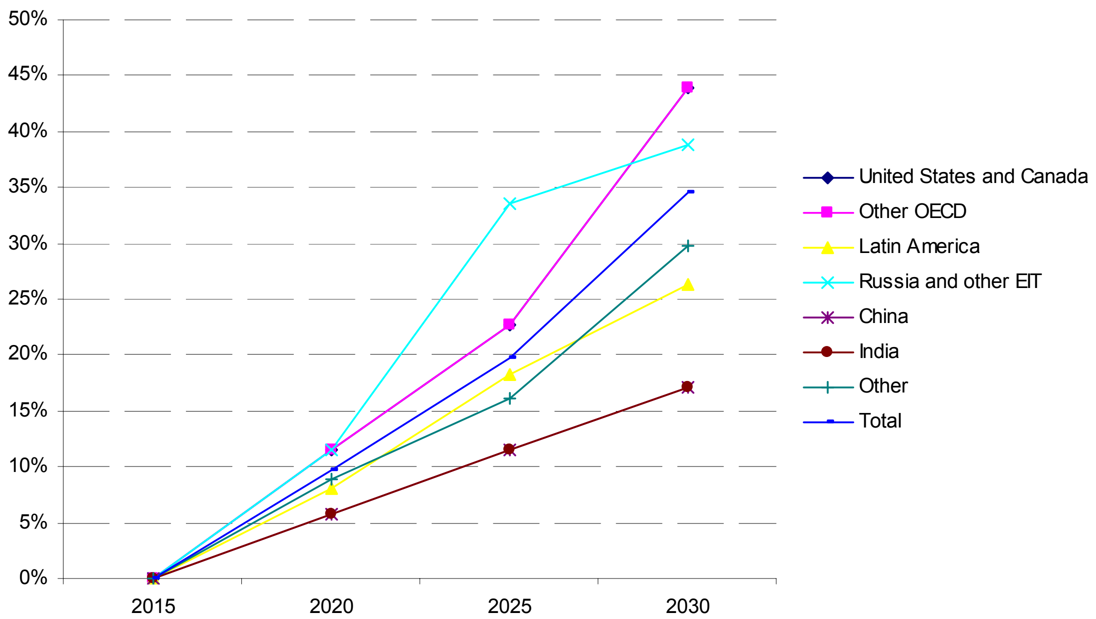

Figure B.2 *The percentage penetration rate of CCS in new natural gas installations*

For industrial sources, an assumption is made that the 70% application of CCS in 2030 will be reached linearly, beginning in 2015. Therefore a penetration rate of 23.3% has been applied for 2020 figures.

Appendix C LULUCF methodology

Regarding the emission reduction potential of Land Use, Land Use Change and Forestry (LULUCF) there are many fundamental uncertainties and complexities, especially because of the non permanent abatement of CO_2 in the sector. Once a tree is harvested or naturally decays the CO_2 is released again. Historic data is often not available. In this study we deal with these uncertainties by the use of scenarios.

Potential emission reductions through LULUCF in the world are calculated based on data from the 36 countries with the largest forest cover. These countries cover around 90% of forests around in the world for the relevant countries (non-Annex I + plus Russia and Ukraine). Standard available data from the FAO Forest Resource Assessment (FRA) 2005[35], IPCC LULUCF Good Practise Guidelines and ENCOFOR[36] are the main input in the calculations. The methodology for the calculations has been discussed in general terms with Mr. Bas Clabbers, senior policy maker and sink expert of the Dutch Ministry of Agriculture, Nature and Food Quality and Mr. Gert-Jan Nabuurs, senior researcher European forest scenario studies at Wageningen University and Research Centre and coordinator lead authors of Chapter 9 on Forestry of the IPCC Fourth Assessment Report (IPCC, 2007). Ecofys bears however full responsibility for the presented results in this report.

The calculation methods for the three main categories Avoided Deforestation, Afforestation and Reforestation and Other Land Use Change are discussed separately in the next paragraphs. The main results are presented in C.1. Full results can be found in the tables at the end of this annex. It should be stressed that in estimates for emission reductions through forestry, much remains uncertain. Therefore we use two different approaches in order to yield a technical potential and more realistic potential, which is further considered to be the market potential (further used in Chapter 4). The latter estimate is considered to be the most realistic as the assumptions therein are a better reflection of real-life conditions.

Table C.1 *Technical LULUCF CO_2 reduction potential in non-Annex I countries.*

Activity	Technical potential ($MtCO_2$/yr in 2020)	Market potential ($MtCO_2$/yr in 2020)
Avoided deforestation	2,271	55-353
Afforestation/Reforestation	7,558-8,958	74-235

The technical potential refers to the physical available potential, without taking into account any constraints such as land rights or planting capacity. In the estimate for the market potential these constraints are taken into account, which is further explained below.

Comparison to other sources

Before going into detail regarding our calculations we will first compare our results presented in the Table C.1 with available leading sources. It must be stated beforehand however, that such comparison is difficult to perform in general, because the underlying data and assumptions of other studies are often not totally clear and/or not readily available. Furthermore it illustrates the significant differences that exist between results of various studies.

The IPCC Fourth Assessment Report (IPCC, 2007; chapter 9) states results according to both global top down studies and local bottom-up studies. According to the IPCC report global top-down studies tend to predict far higher mitigation potentials than local studies. It is also stated

35 http://www.fao.org/forestry/site/28679/en/.
36 http://www.csi.cgiar.org/encofor/forest/index_res.asp.

that further research is needed to narrow the gap between local bottom up and global top down studies. In our approach we encountered the same difficulties and we also used two very different approaches to calculate the technical and market potential.

According to the IPCC report, global deforestation accounts for 20% of the annual anthropogenic GHG emissions (Gullison et al., 2007, IPCC WG 1 2007). Global economic mitigation potential in 2030 estimated from bottom-up studies at a carbon price of 100 US$/t$CO_2$-eq amounts 16-31 Gt$CO_2$-eq/yr. Regarding avoided deforestation, the IPCC report states that the current annual emissions from deforestation in the 1990s are 5.8 GtCO_2/yr (medium agreement, medium evidence). Global top-down models mentioned in the IPCC report predict a mitigation potential of 4.0 GtCO_2-eq/yr in 2030 at carbon prices up to 100 US$/t$CO_2$-eq.

In our calculations, based on FAO statistics for the selected countries, we calculated with yearly average BAU emissions from deforestation of 2.3 GtCO_2/yr between 2012 and 2020, thus considerably lower than the mitigation potential in 2030 for reduced emissions from deforestation in the IPCC report. Although the assumptions in the IPCC report were studied in detail, one explanation might be that the FAO statistics we used for deforestation are net deforestation figures (reforestation is subtracted). Furthermore, in our study we did not take into account Annex I countries.

Kinderman et al (2006) state that global carbon stocks in forest biomass are decreasing by 1.1 Gt of carbon annually, owing to continued deforestation and forest degradation. This is equal to 4.0 Gt of CO_2 annually. The authors further state that Baseline scenario calculations show that close to 200 million hectares (Mha) or around 5% of today's forest area will be lost between 2006 and 2025, resulting in a release of additional 17.5 GtC. This corresponds to 64 GtCO_2 in this period of time, or 3.2 GtCO_2 per year. This is again considerably higher than our estimate of 2.3 Gt per year on average. The authors also state that an incentives of 6 US$/tC for vulnerable standing biomass paid every 5 year will bring deforestation down by 50%. This is considerably higher than our realistic (market) potential. The amount of hectares lost between 2006 and 2025 can be compared to our calculations on a yearly basis (roughly 10 Mha per year).

Regarding afforestation/reforestation, the IPCC report states a mitigation potential that is equal to the mitigation potential of avoided deforestation, namely 4.0 GtCO_2-eq/yr in 2030 at carbon prices less than or equal to 100 US$/t$CO_2$-eq (global model results). Our technical mitigation potential of 7,558-8,958 Mt/yr in 2020 is thus considerably higher, and is therefore not used further in this study.

For all forestry mitigation options together (afforestation, reduced deforestation and forest management), the IPCC report (2007) predicts a mitigation potential of 13.8 GtCO_2-eq/yr in 2030 at carbon prices less than or equal to 100 US$/t$CO_2$-eq based on global top-down models. The IPCC report predicts an economic potential for these activities at costs up to 100 US$/t$CO_2$-eq of 1.3-4.2 Gt$CO_2$-eq/yr (average 2.7 Gt$CO_2$-eq/yr) in 2030, based on bottom-up studies. About 50% can be achieved at a cost under 20 US$/t$CO_2$-eq (around 1.6 Gt$CO_2$/yr) with large differences between regions. This economic potential from IPCC bottom-up studies is in the range of our economic potential of 530-3,141 Mt per year in 2020 at an average cost of 7.4 US$/t$CO_2$ for avoided deforestation up to US$ 89 per ton for afforestation/reforestation. It must be noted however that the IPCC report also includes improved forest management, which contributes approximately 40% to the total economic mitigation potential. Therefore, the IPCC results can be compared to the lower part of our predicted range.

Avoided deforestation

It is important to clarify beforehand that our calculations are based on reduced emissions from deforestation. We do not propose to issue carbon credits for standing carbon stocks, only for carbon stocks that result from avoided deforestation. This means that not every tonne of carbon in existing forests represents carbon credits.

Technical potential
The technical potential in $MtCO_2$ per country is calculated by multiplying the total amount of hectares of forest for this country that could be saved by 2020 when compared to 2019, with the average carbon intensity per hectare of forest in this country. The basis for the calculations of forest area where deforestation could theoretically be avoided, i.e. forest protected, are the yearly deforestation rates of the FRA 2005[37], which are linearly extrapolated to 2020. The difference between the calculated forested area in 2012 (2,956 Mha) and 2020 (2,874 Mha) could be protected theoretically throughout this entire period is 81 Mha. 12 Mha thereof is avoided between 2019 and 2020; this amount is taken into account to come to our technical potential

The carbon intensity of forests around the world are calculated by multiplying the average aboveground biomass content (in tonnes) in forests per country[38] in tonnes per ha by 0.45, to come to tonnes C content and multiplying that by 3.67 (the difference in atomic weight between C and CO_2). This carbon intensity (CO_2 stored per ha) of forests is then multiplied with the previously calculated hectares cumulatively deforested under BAU in 2020 to come to the theoretic CO_2 reduction potential through avoided deforestation per country in 2020 (2.3 $GtCO_2$/yr for all countries together).

An important underlying assumption in this calculation is that carbon credits for avoided deforestation can be claimed once. It is not known however what the actual period of time will be for which carbon credits could be claimed in the future, as somehow these credits will have an expiry date to justify the fact that these are non-permanent reductions. It is unsure how a system for compensating for emission reduction from deforestation will be functioning in the future. It might also be that such a system will resemble the current system for carbon sequestration in sinks in Annex I countries.

Market potential
It is very unclear at this point in time what a scheme with incentives to avoid deforestation will look like in the future and negotiations will have to show. Basically the following approaches can be distinguished in the discussions:

- An integrated approach with national targets, in which all carbon credits from avoided deforestation can be sold directly to the post 2012 global carbon market.
- A compensated reduction scheme with national targets. Under such a scheme countries would receive carbon credits for avoided deforestation, however such carbon credits could not be sold on the international carbon market.
- A fund-based approach not generating carbon credits (dependent on Official Development Aid or institutional financing).

Various disadvantages are mentioned regarding the integrated approach:

- Avoided deforestation has the potential to flood the carbon market. If avoided deforestation (as CDM or national approach) would be included in a future climate regime, targets would have to be adapted accordingly. This is however difficult as the magnitude of potential credits and their uncertainty is larger than for other sectors.
- There is a problem in baseline setting. It is even harder to set a baseline for avoided deforestation than for other project types. There is the undesirable incentive to foster deforestation in order to manipulate the baseline.
- Leakage (protecting areas might lead to deforestation elsewhere).

[37] Forest definition: minimum of 0.5 ha of wooded area, canopy of 10%, productive plantations for industrial purposes excluded. Deforestation rate for the period 2000 - 2005.
[38] IPCC LULUCF Good Practice Guidelines table 3A.1.4.

The major advantage of the integrated market proposal is its ability to incentivise large amounts of funding (e.g., from the private sector), while its major downside is the potential to disrupt the global carbon market which is already functioning well. A fund approach prevents disruption to the carbon market, but would likely lack enough resources to produce large-scale results.

Countries differ with respect to their preferences for the mentioned systems. Brazil is lobbying separately for a fund for Annex I countries to donate money, so Brazil can protect its forests. Brazil does not accept a national target for avoided deforestation, because it could lead to either hot air or else for Brazil to buy carbon credits (Centro Clima, 2007) and also because in general Brazil probably does not want to set a precedent by accepting a national forestry target for other sectors. Furthermore Brazil does not approve of linking national credits from avoided deforestation to any market mechanism, because it does not want fossil fuel emissions to be compensated by a reduction of emissions from deforestation. The situation in Brazil is described in more detail at the end of this annex. The Dutch governmental position is that reducing emissions from deforestation should be included in an international climate regime, preferably via a market-based approach[39].

A combination of the above mentioned approaches, called the Dual Market Approach, was proposed by CCAP (Ogonowski et al, 2007). The Dual Markets approach specifies the creation of a new carbon market for emissions reductions from deforestation and degradation that is linked with the overall reductions achieved by developed countries in the post-2012 timeframe, but is only partially fungible with the post-2012 global carbon market. Developed countries would commit a percentage of their post-2012 target to come from the REDD (reduced emissions from deforestation and degradation) market. For example, if a country committed to an overall 30% reduction, they could also commit that 5% of that reduction would be generated through financing REDD activities in developing countries—the other 25% would come through domestic reductions or through purchasing reductions in the non-REDD post-2012 carbon market. By applying a maximum to the amount of carbon credits from REDD activities that Annex I countries could use to fulfil their national Kyoto targets, the thread of flooding the existing carbon markets is reduced. The REDD market would have the chance to mature first (become less volatile) and to solve existing problems with establishing baselines.

Because of the uncertainties that exist regarding inclusion of avoided deforestation in any scheme under the climate regime and the uncertainties regarding baseline setting and monitoring, we decided to construct three different scenarios for the realistic potential of avoided deforestation. Basically in the scenarios we make a selection of countries that we consider likely to be eligible for inclusion in some sort of scheme under the climate regime and furthermore we assume a percentage of deforestation that could be avoided.

- In Scenario 1 we assume that the countries forming the Coalition of Rainforest Nations[40] that are now actively promoting avoided deforestation to be part of some sort of scheme under the climate regime plus Brazil and Indonesia, will actually be able to make use of this possibility in 2020. Other countries are considered unlikely to have monitoring and other relevant policies in place at that time. Most countries do not have reliable historic deforestation data, the only exception is Brazil. Furthermore we assume in this scenario that these countries will be able to reduce deforestation by 2020 by 25% compared to the baseline scenario. This results in 0.35 $GtCO_2$/yr sequestered in 2020.
- In Scenario 2 we assume that only the presumably very active countries Brazil, Papua New Guinea and Indonesia will be eligible and complying to a monitoring standard. Like in

[39] Comment Bas Clabbers.

[40] Countries forming the Coalition of Rainforest Nations are: Bolivia, Cameroon, Congo, Congo DRC, Costa Rica*, Gabon, Guatemala* and Papua New Guinea. (*not included in our study because not selected within the 36 countries with largest forest cover in the world).

Scenario 1 we assumed that these countries will be able to reduce deforestation by 2020 with 25% compared to the baseline scenario. This results in 0.28 $GtCO_2$/yr sequestered in 2020.

- In Scenario 3 we assume the same countries to be eligible as in scenario 2, but under the assumption that they will not be able to reduce deforestation with 25%, but only with 5%. This results in 0.06 $GtCO_2$/yr sequestered in 2020.

Costs of CO_2 *abatement from avoided deforestation*
The costs of abatement of CO_2 emissions through avoided deforestation were calculated following the IPCC (2007) for all countries. Abatement costs from a range of top-down modelling studies are given in three costs range: 1-20 \$/tCO_2, 20-50 \$/tCO_2, and 50-100 \$/tCO_2 for three non-Annex I regions. The share of the technical potential is given for each cost range. We took these shares and the upper limit of each class to calculate the abatement cost for the potentials per country mentioned in Table C.1.

Afforestation and Reforestation

Technical potential
The estimates for the technical potential is calculated by assuming a global average annual growth rate of 4 tonnes C per ha[41], corresponding to 15 tonnes CO_2 per ha per year. The available area in hectares times sequestration potential in CO_2 per hectare results in a theoretic global CO_2 reduction potential. The basis for the calculations of area theoretically eligible for afforestation or reforestation as defined under the CDM is the data from ENCOFOR[42]. These data quantify available land for afforestation or reforestation CDM per country, taking into account the limits posed by elevation and aridity as well as excluding water bodies, tundra, agricultural land, and residential land and conservation areas. National CDM forest definitions set by the DNAs of the 36 selected countries were used.

For those countries that have not yet set their CDM forest definition, we calculated two scenarios:

- A scenario using the minimal value in the range given by UNFCCC. The given range to define tree vegetation as forest, dictates a minimal canopy cover between 10 -30%. Thus we have set the minimum limit at 10% (leading to maximal existing forest area and thus minimal area available for AR CDM). This scenario leads to 515 Mha available for all relevant countries together. Multiplying with the average CO_2 sequestration per hectare results in a total of 7.6 $GtCO_2$/yr sequestered in 2020.
- A scenario using the maximum value in the range given by the UNFCCC (30%). This results in 611 Mha of eligible land and consequently in 9.0 $GtCO_2$/yr sequestered in 2020.

Market potential
As was stated before, there is a big gap between theoretic potential from global top-down studies and a more realistic potential from local bottom-up studies. Many problems are related to land rights and proving additionality. Illustrative is the volume of current realised CDM projects under CDM and the current pipeline. We were suggested by Gert-Jan Nabuurs to take as a starting point the current reforestation rate of plantations. In the FRA it is stated that globally the area under forest plantations increases by 1% per year. We now calculated 3 scenarios, with the plantation size in 2005 (FRA) as the base year (65 Mha):

1) An increase in the growth rate of plantations by 50% due to CDM incentives as of 2007, thus a growth rate of plantations of 1.5%. This results in only 5 Mha of forests due to CDM in 2020 (the difference in hectares of plantation in 2020 between the plantation size applying a BAU growth rate of 1% and the plantation size in 2020 when applying our

41 Reasonable according to Mr. Gert-Jan Nabuurs
42 Environment and Community based framework for designing Afforestation, reforestation and revegetation projects in the CDM: methodology development and case studies (ENCOFOR) http://www.csi.cgiar.org/encofor/forest/index_res.asp

scenario rate of 1.5%). Multiplying with the annual CO_2 sequestration of forests of 14.67 tonne per ha leads to a potential of 74 $MtCO_2$/yr sequestered in 2020.

2) Similar assumptions but a 100% growth in plantation rate. This leads to 152 $MtCO_2$/yr sequestered in 2020.
3) Idem but a 150% increase in plantation growth rate. This leads to 235 $MtCO_2$/yr sequestered in 2020.

In general it must be noted that there are a lot of problems with proving additionality in afforestation/reforestation projects. This may reduce market potential further, especially since the EB could be seeking to tighten the rules for projects that could be profitable by themselves, i.e. without additional revenue from carbon credits.

Costs of CO_2 abatement from afforestation/reforestation

The costs of afforestation/reforestation are estimated only very roughly. We assumed costs for establishing and maintaining a forest (mainly labour costs and costs of material) at US$ 675 per hectare for tropical dry forests, US$ 1,350 per hectare for tropical wet forests and US$ 4.000 per hectare for temperate and boreal forests. An internal forestry expert within Ecofys estimated the division in forest types for all relevant countries. By applying this division per country to the costs per hectare we arrived at average costs per hectare per country. We did not take into account costs for acquiring lands or putting infrastructure in place, because these costs can vary substantially and no reliable databases exist. The resulting costs per hectare vary between US$ 46 to US$ 272 per hectare, on average US$ 94. It should be noted these costs are of course for a large part covered by revenues from forestry activities.

Other Land Use Change

In general all other land-use projects are still far from inclusion under either reduction schemes with national targets or project based approaches like CDM. Currently improved forest management and reducing CO_2 emissions from improved tillage in agriculture is under discussion, but this still only applies to Annex I countries. In relation to avoided CO_2 emissions from the soil from peat lands by stopping drainage it must be said that there are no reliable historic data and it seems to be far from inclusion under a Kyoto scheme. Therefore we disregarded of these types of projects.

Box C.1. *The Brazilian case* (based on Centro Clima (2007)

Brazil is discussed in more detail in this study because of its impact on the results in this study (Brazil represents 16% of the total forested area of the countries considered relevant in this study), because of availability of data from local reviewers (Centro Clima, 2007) and to illustrate complexities and uncertainties regarding emissions from LULUCF. First deforestation in Brazil is discussed, after this afforestation/reforestation.

Current deforestation rate and deforestation potential
The rate of deforestation from the last years experienced a substantial drop. The average deforestation since 1989 is 18,016 km^2 per year with peak year 1995 at 29,059 km^2 and this dropped to 14,039 km^2 in 2006. For the long term, the speed of deforestation is estimated by Britaldo at al. (2005, in Centro Clima, 2007). Under their business as usual scenario, the annual rate of deforestation increases from 23,000 km^2 per year (0.5% relative to forest cover in 2005) to around 35,000 km^2 per year in 2020 (0.7%). In their least aggressive scenario, that takes into consideration strong governance without new road paving, deforestation decreases to 12,000 km^2 per year in 2020 (0.25%). In this report, for the theoretic potential we extrapolated the BAU annual deforestation rate for Brazil between 1990 and 2005 (0.6%) to 2020. For the realistic potential from avoided deforestation we assume a 5-25% reduction of deforestation in Brazil. The costs of CO_2 reduction were estimated by da Motta, 1999 (in Centro Clima, 2007) at 3.7 US$/tC, or 1 US$/tCO_2. These costs were used as a reference in this study.

Drivers for deforestation
Drivers for deforestation in Brazil are: cattle raising, agricultural production, land speculation by ‘grileiros’, infra-structure development (mainly paving of roads, and also new roads opening caused by large projects such as hydropower plants, e.g), wood industry, agrarian reform and illegal logging. Land use is a very sensitive issue in Brazil, because of the lack of access to land by millions of people in rural areas. However, the country has a huge availability of land for agriculture (90 Mha) and the agriculture activity expansion does not necessarily imply deforestation (source: Brazilian Ministry of Agriculture).

Hydropower plants are another very sensitive issue in Brazil. There is a vast resource which is still unexplored. It happens that about 70% of the hydraulic potential to be taken advantage of is in Amazonia and in the Cerrado. The average of the area being flooded by existing power plants is 0,52 km^2/MW. The official plan of Electrical Energy Expansion between 2006-2015 projects that the planned plants will have a flooded area average of 0.27 km^2/MW. Considering expansion between 2006-2015, the total area inundated by hydropower plants will be 0.54 Mha), that represents 0.14% of Amazon forests plus the areas of environment protection in 2020.

National deforestation policy
The drop in deforestation rate mentioned before is being attributed to structural changes recently introduced, including ‘real time’ monitoring using satellite data, corruption control and enforcement. The comprehensive Plan of Action for the Prevention and Control of Deforestation in the Legal Amazonia (Plano de Acao para a Prevencao e Controle do Desmatamento na Amazonia Legal) is an example of the Brazilian Government effort to address deforestation in the Brazilian Amazonia. The amplification of the Legal Reserve Areas in Amazonia from 50% to 80%, launched after detecting the high rate of deforestation in 1994-1995, was a measure to curb deforestation. A new government programme was officially created (law no. 11.284/2006), which allows for public forest concessions. This aims at tackling land speculation by grileiros. Through public forest concessions it is possible to sustainably exploit the forests while maintaining their status as forest. In the first 10 years (2008-2018) this programme targets to include 13 Mha. This could be a considerable contribution to slow down deforestation, since yearly deforestation averages 1.8 Mha/yr as was mentioned before.

The Brazilian government currently does not accept to include forest conservation as part of any carbon trading mechanism (Centro Clima, 2007). The same applies to deforestation reductions based on a national target, presumably due to the risk of setting the wrong baseline (creating hot air or a gap between actual emissions and targeted emissions). Leakage is another potential problem. Brazil is currently lobbying for a non market-based fund to raise money for protecting its forests.

Technical potential from Afforestation/Reforestation in Brazil
There is a huge potential for reforestation projects in the Brazilian Amazonia, particularly for native species for ecological purpose in degraded lands, which account for over 20 Mha (Nobre, 2001, in Centro Clima, 2007). The area of forest plantation needed by 2020 to meet demand is the sum of existing plantations (5.6 Mha) and new plantations needed by 2020 (7.1 Mha, source Brazil Silviculture Society, SBS, 2002). The total theoretic potential in hectares available for afforestation/reforestation in 2020 is thus assessed to be 32.7 Mha. Of course it is unclear which part of these hectares could realistically be reforested by 2020.

In this report the Encofor tool was used to assess the total amount of hectares theoretically available for afforestation/reforestation. The results from the Encofor tool are that 40 Mha could be reforested when assuming a canopy cover of 10% (an area with 10% canopy cover is already called a forest, hence less land available to be reforested) and a stunning 226 Mha when assuming a canopy cover of 30% (the official canopy cover chosen by the Brazilian government under CDM regulations).

For the low estimate (more realistic) for the technical potential, we assumed 5.5 Mha of plantations available in 2007 and a BAU growth rate of 1%. Furthermore we calculated different growth scenarios exceeding BAU as a result of CDM incentives (total growth rates of 1.5%, 2% and 2.5% respectively). Applying these growth rates leads to respectively 6.7, 7.1 and 7.6 Mha of plantations in 2020. Of course only part of this growth can be assumed CDM incentivised.

Centro Clima (2007) identified 5.6 Mha of plantations in 2005. Because an additional 7.1 Mha is needed to fulfil demand in 2020, Brazilian scenarios assume total plantations to be 12.7 Mha in 2020, exceeding all of our scenarios. Of course this is not growth incentivised by CDM. We therefore kept using the CDM incentivised prediction described in the previous paragraph. The costs found by Centro Clima in Brazilian literature range from 0.27 - 1.4 US$ per ton CO_2 for plantations to 4.4 - 5.5 US$ per ton CO_2 for native species for ecological purposes in degraded lands.

In this study we assumed 78 US$/t$CO_2$ for average afforestation/reforestation (mix of plantations and native species for ecological purpose in degraded lands) based on the assumptions mentioned in the part on afforestation/reforestation. The significant difference between the costs suggested by Centro Clima and the costs that were used in the MAC curves in this report cannot fully be explained, because not all assumptions are known. One difference however is the higher growth rate for afforestation/reforestation assumed by Centro Clima (7.3 tC/ha compared to 4 tC/ha used in the MAC curves in this report)

Table C.4 *Potential figures for avoided deforestation*

Avoided deforestation		Market potential 2020 (MtCO2/yr)		
Country	Technical potential 2020 [$MtCO_2$/yr]	Scenario 1 (25% reduction deforestation rate of selected countries	Scenario 2 (Indonesia, Papua New Guinea and Brazil 25% reduction deforestation rate)	Scenario 3 (Indonesia, Papua New Guinea and Brazil 5% reduction deforestation rate)
Angola	10			
Cameroon	38	9		
Central African Republic	4			
Congo	8	2		
Democratic Republic of the Congo	158	39		
Ethiopia	15			
Gabon	-			
Madagascar	17			
Mozambique	5			
Nigeria	65			
Sudan	10			
United Republic of Tanzania	31			
Venezuela (Bolivarian Republic of)	101			
Zambia	60			
Rest Africa	228			
Total Africa	*749*	*51*	-	-
Afghanistan	1			
Bangladesh	0			
China	-			
India	277	69	69	14
Indonesia	0			
Kazakhstan	4			
Lao People's Democratic Republic	33	8		
Malaysia	33			
Myanmar	9			
Nepal	-			
Papua New Guinea	13	3	3	1
Rest Asia and Oceania (excl. Japan, Turkey, Israel, Australia, New Zealand)	103			
Total Asia & Oceania	*474*	*81*	*73*	*15*
Argentina	14			
Bolivia	72	18		
Brazil	815	204	204	41
Chile	-			
Colombia	19			
Guyana	-			
Mexico	25			
Paraguay	14			
Peru	27			
Suriname	-			
Rest Latin America & Carribean	60			
Total Latin America & Carribean	*1,048*	*222*	*204*	*41*
Russian Federation	-			
Ukraine	-			
Total Relevant Countries	*2,271*	*353*	*276*	*55*

Table C.5 *MAC Afforestation/reforestation*

Afforestation/ Reforestation Country	Technical potential			Market potential		
	Scenario 1: 10% canopy cover or choice country	Scenario 2: 30% canopy cover or choice country	Total abatement cost	Scenario 1 (100% increase forestation rate)	Scenario 2 (50% increase forestation rate)	Scenario 3 (150% increase forestation rate)
	[$MtCO_2$/yr 2020]		[US$/$tCO_2$]		[$MtCO_2$/yr 2020]	
Angola	20	183	46,12	0,3	0,1	0,5
Cameroon	9	106	0,10	-	-	-
Central African Republic	2	81	92,15	0,0	0,0	0,0
Congo	28	28	92,15	0,1	0,1	0,2
Dem.Reb. Of Congo	331	331	0,10	-	-	-
Ethiopia	154	154	91,46	1,1	0,6	1,8
Gabon	10	23	46,12	0,1	0,0	0,1
Madagascar	361	361	69,13	0,5	0,3	0,8
Mozambique	11	112	59,93	0,1	0,0	0,1
Nigeria	64	351	46,12	0,8	0,4	1,3
Sudan	1	26	50,73	11,0	5,3	17,0
Tanzania	19	121	64,53	0,3	0,2	0,5
Zambia	14	108	59,93	0,2	0,1	0,3
Total Africa	*1.026*	*1.986*	*55,27*	*14,6*	*7,1*	*22,6*
Afghanistan	38	40	0,10	-	-	-
Bangladesh	36	43	91,80	0,5	0,2	0,7
China	1.104	1.104	195,78	66,4	32,2	102,6
India	819	819	78,00	2,5	1,2	3,8
Indonesia	57	228	128,28	7,9	3,8	12,2
Kazachstan	24	28	272,83	2,1	1,0	3,3
Lao People's Dem. Rep.	1	15	92,15	0,5	0,3	0,8
Malaysia	4	13	92,15	3,7	1,8	5,7
Myanmar	12	40	92,15	1,6	0,8	2,5
Nepal	22	46	200,55	0,1	0,0	0,2
Papua New Guinea	6	22	92,15	0,2	0,1	0,3
Total Asia & Oceania	*2.123*	*2.397*	*121,45*	*85,4*	*41,4*	*132,1*
Argentina	412	412	118,74	2,9	1,4	4,4
Bolivia	113	113	164,42	0,0	0,0	0,1
Brazil	3.313	3.313	78,34	12,5	6,1	19,4
Chili	41	41	227,49	6,2	3,0	9,6
Colombia	315	315	101,01	0,7	0,4	1,1
Guyana	9	19	0,10	-	-	-
Mexico	126	126	109,87	0,2	0,1	0,3
Paraguay	13	13	46,12	0,1	0,0	0,2
Peru	22	22	123,34	1,8	0,9	2,7
Suriname	0	2	92,15	0,0	0,0	0,0
Venezuela	45	200	0,10	-	-	-
Total Latin America & Carribean	*4.409*	*4.575*	*97*	*24,4*	*11,8*	*37,7*
Russian Federation	n.a.	n.a.	272,83	27,7	13,4	42,8
Total	*7.558*	*8.958*	*89,0*	*152,1*	*73,8*	*235,1*

Appendix D Mitigation options from regional reviews

In the responses of the reviewers as referred to in Section 3.6 the following mitigation options were identified in addition to those included by ECN and Ecofys. The options for which both abatement potential and cost were provided were added to the database used in Chapter 3 and 4.

Table D.1 *Mitigation options provided by regional reviewers.*

Country	Sector	Option	Potential 2020 MtCO$_2$-eq/yr	Abatement cost $/tCO$_2$-eq	Provided by
Brazil	Power	Small Hydro	-115.68	15.23	Centro Clima
Brazil	Power	Sugar-cane bagass	30.90	19.57	Centro Clima
Brazil	Power	Wind power	51.09	19.84	Centro Clima
Brazil	Power	Sugar-cane bagass (Ethanol	30.90	1.49	Centro Clima
Brazil	Transport	Efficiency gains	-182.50	6.21	Centro Clima
Brazil	Transport	Flex fuel vehicles	30.10	21.2	Centro Clima
Brazil	Transport	Flex fuel vehicles (increasing in the domestic supply)	30.10	1.8	Centro Clima
Brazil	Avoided deforestation	Public Forest for concession (target)	59.00	0.8	Centro Clima
Brazil	Avoided deforestation	Other policies reducing deforestation at 300,000 ha/yr	147	1	Centro Clima
Brazil	Afforestation/reforestation	Native species for ecological purpose in degraded lands	72	16-20	Centro Clima
Brazil	Afforestation/reforestation	Industrial purpose	2,6	1-5	Centro Clima
China	Power	Wind power	60	n/a	CREIA
China	Residential	Solar thermal	59.5	n/a	CREIA
Fiji	Power	Hydro	1.02	n/a	IT Power India
Fiji	Power	Solar	0.03	n/a	IT Power India
Fiji	Power	wind	0.56	n/a	IT Power India
Fiji	Power	Biomass	1.09	n/a	IT Power India
Samoa	Power	Hydro	0.25	n/a	IT Power India
Samoa	Power	Biomass	0.15	n/a	IT Power India
Nepal	public	Compact Fluorescent Lights	1.01	n/a	IT Power India
Nepal	Power	Energy efficient motors & CFL	0.76	n/a	IT Power India
Nepal	Power	Biomass for Electricity Generarion	2.47	n/a	IT Power India
Egypt	Industry	Efficient industrial equipment and maintenance	10	-12	ENDA
Egypt	Transport	Transportation	2	-12	ENDA
Egypt	Power	Electricity generation	8	-1	ENDA
Zimbabwe	Power	Increased hydropower	5	5	ENDA
Zimbabwe	Residential	Efficient furnaces	2	66	ENDA

n/a: not available.

Appendix E Abatement potential of project types and related technology options following the 'Methodology approach' (Section 5.1.2)

Method.	Type	Technology options	Abatement potential [$MtCO_2eq$/yr in 2020]
AMS I.C	Thermal energy for the user with or without electricity	solar thermal water heaters and dryers, solar cookers, energy derived from renewable biomass for water heating, space heating or drying, biomass-based co-generating systems	35.1
AMS I.D	Grid connected renewable electricity generation	photovoltaics, hydro, tidal/wave, wind, geothermal and renewable biomass	203.3
AMS II.A	Supply side energy efficiency improvements - transmission and distribution	upgrading the voltage on a transmission line, replacing a transformer, increased insulation of the pipes in a district heating system	20.7
AMS II.B	Supply side energy efficiency improvements - generation	efficiency improvements at power stations and district heating plants and co-generation	210.4
AMS II.C	Demand-side energy efficiency programmes and activities for specific technologies	adoption of energy-efficient equipment, lamps, ballasts, refrigerators, motors, fans, air conditioners, appliances, etc	86.9
AMS II.D	Energy efficiency and fuel switching measures for industrial facilities	efficient motors, switching from steam or compressed air to electricity etc	307.0
AMS II.E	Energy efficiency and fuel switching measures for buildings	efficient appliances, better insulation and optimal arrangement of equipment, switching from oil to gas	5.8
AMS II.F	Energy efficiency and fuel switching measures for agricultural facilities and activities	less irrigation, less and smaller tractors, longer lifetime of tractors and less farm equipment, reducing fuel use in agriculture, such as reduced machinery use through, e.g. the elimination of tillage operations, reduction of irrigation, use of lighter machinery, etc	
AMS III.B	Switching fossil fuels	fuel switching in existing industrial, residential, commercial, institutional or electricity generation applications	57.5
AMS III.C	Emission reductions by low-greenhouse gas emitting vehicles	low-greenhouse gas emitting vehicles	76.0
AMS III.E	Avoidance of methane production from decay of biomass through controlled combustion	controlled combustion of wastes from solid waste disposal sites or waste that would have otherwise been left to decay under clearly anaerobic conditions	
AMS III.F	Avoidance of methane production from decay of biomass through composting	aerobic treatment by composting and proper soil application of the compost	

Method.	Type	Technology options	Abatement potential [$MtCO_2eq$/yr in 2020]
AMS III.H	Methane Recovery in Wastewater Treatment		
AMS III.I	Avoidance of methane production in wastewater treatment through replacement of anaerobic lagoons by aerobic systems	anaerobic lagoons (without methane recovery), are substituted by aerobic systems	
AMS III.J	Avoidance of fossil fuel combustion for carbon dioxide production to be used as raw material for industrial processes	replace the carbon dioxide produced by fossil fuel combustion with carbon dioxide captured from a renewable biomass source	
AMS III.K	Avoidance of methane release from charcoal production by shifting from pit method to mechanized charcoaling process	producing charcoal from pit is replaced by new facility(ies) equipped with recovery and flaring/combustion of methane generated in the production process	
AMS III.L	Avoidance of methane production from biomass decay through controlled pyrolysis		
AMS III.N	Avoidance of HFC emissions in rigid Poly Urethane Foam (PUF) manufacturing	Replacement of blowing agents used in the baseline such as HFC-134a, HFC-152a, HFC-365mfc and HFC-245fa with non-GHG blowing agent such as pentane	
AM 44	EE for industries	boiler rehabilitation and replacement in industrial and district heating sectors	19.6
AM 20	EE in service sector	water pumping efficiency improvement	
AM 46	EE for household	replacement of incandescent by compact fluorescent bulbs	29.9
NM18	Energy distribution	introduction of new primary district heating systems	
NM 197	Energy demand	power saving through accelerated replacement of electrical equipment with variable load under a PoA	
NM 211	Energy demand	efficiency improvement of fossil-fired steam boiler (systems) by boiler replacement or rehabilitation	
NM 205	Transport	improving the fuel efficiency of vehicle fleets	137.8
NM 142	Transport	adding 10% of palm oil methyl ester to diesel[43]	141.0
Uncategorised	Transport	All other unspecified efficiency measures, increasing the share of public transport, BRT and switching from gasoline to CNG	259.5
TOTAL			1590.64

43 Any replacement of diesel by biodiesel is considered here regardless of the blending proportions.