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Prioritising Opportunities under the Clean Development Mechanism

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Executive Summary

The Clean Development Mechanism (CDM) is one of several 'flexibility mechanisms' established by the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change. The Protocol specifies legally binding limits on the emissions of greenhouse gases from most industrialised countries so that collectively, by the period 2008 to 2012, these emissions will be at least 5 % lower than in 1990. To help minimise the costs of achieving these targets, the CDM allows governments or companies in industrialised countries to invest in emission reduction projects in developing countries, where abatement can be cheaper, in order to meet their emission objectives. Projects that qualify under the CDM must lead to emissions reductions that are additional to those which would have happened anyway and should also contribute towards achieving sustainable development in the host countries.

The CDM therefore has the potential to channel billions of pounds from industrialised to developing countries while offering them access to the latest 'clean' technologies and helping to promote a more environmentally sustainable path for their economies. This study was designed to assist the Department for International Development in understanding the extent to which the CDM might bring additional funding to support projects that are in line with its mission to promote global sustainability and reduce poverty. This has been done by developing a framework to screen possible abatement projects and so identify those that could provide both cost-effective greenhouse gas emission reductions and achieve other environmental, social and development benefits. The approach was then applied to China, India and South Africa in a number of case studies

The screening framework involves a three-step process to evaluate greenhouse gas mitigation opportunities that may be appropriate to the CDM. These screening layers are:

- techno-economic;
- environmental;
- social and development.

The economic screening of projects uses cost-abatement curves to enable the net cost and greenhouse reduction potential of projects from different sectors of the economy to be evaluated on a common basis. Projects that are shown to be financially attractive are then judged against a qualitative set of sustainability criteria. These include environmental effects such as impacts on local air quality, water resources and soil conservation and social and development benefits in terms of factors such as employment creation, poverty reduction and rural development. No specific screen has been included for the additionality of projects, due to the considerable uncertainty surrounding its interpretation in the context of the CDM. However, this could also be an important factor in determining the eligibility of greenhouse gas emission reduction projects under the CDM.

The screening process has been applied in the case studies to identify and prioritise a portfolio of opportunities in China, India and South Africa. Where possible, these have been confirmed with locally based experts or published information as being in line with national development needs and so likely to be suitable for the CDM. However, it should be noted that depending on the additionality and sustainability criteria that are finally agreed by the international community, some of opportunities identified in this analysis could be excluded from the CDM.

A second stage of analysis has then considered the potential involvement of the UK in the CDM and the benefits that this could have to both the UK and developing countries. This has involved both an economic analysis of the role that the CDM could have in helping the UK to meet its greenhouse gas reduction targets and discussions with UK companies about their attitudes towards the use of this new mechanism. This concluded that the CDM can be a cost-effective element of the UK's climate change strategy that would enable the UK to offset some of the costs associated with meeting its domestic target to reduce CO_2 emissions, while providing an important source of investment in developing countries. These results were reinforced by the findings from a survey of UK industry. This showed that many companies believe the CDM could have a useful role in helping them to make greenhouse gas emission reductions in the most cost-effective way, while also noting that social and development factors would be a consideration in project selection.

Based on the results of both the case studies and the later analysis of the UK situation, the table overleaf identifies a portfolio of greenhouse gas mitigation opportunities that may be of particular relevance to the CDM, with the options highlighted in bold considered to be most attractive.

In the light of the conclusions of this project, a number of recommendations have been made to enable both developing countries and the UK to get maximum benefit from the opportunities offered by the CDM.

- Further work with governments and experts in a number of smaller developing countries to develop the institutional and technical capacity necessary to identify and promote opportunities that are in line with national development needs and are suitable for CDM funding.
- Develop closer liaisons with other government initiatives such as the DETR web-site 'Business Opportunities and the Kyoto Mechanisms' to provide further information to UK business on the scale of opportunities and priority areas for CDM activities. For instance, a summary of this report could be placed on this web-site.
- After COP 6, organise a DFID/DETR/DTI sponsored conference to promote the potential role of the CDM in helping key sectors of UK industry to meet their current and future greenhouse gas emission targets.

Prioritised CDM opportunities in China, India and South Africa

	CO_2 abatement	Typical abatement costs	Contribution to sustainable development	Of interest to UK companies
China				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	**	***	**	**
Low cost paper and pulp measures	*	***	*	***
Aluminium smelting improvements	*	***	*	***
Foundry processes improvements	*	***	*	***
Commercial building improvements	*	***	*	**
Domestic and commercial lighting improvements	**	***	*	**
CCGT	***	**	**	***
Biogas digesters in the domestic sector	**	**	***	*
India				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	*	***	**	**
Paper mills capacity management	*	***	*	*
Improved domestic cooking stoves	*	***	***	*
Improved grinding in cement	*	***	*	***
Low cost steel plant measures	**	***	**	***
Aluminium smelting best practice	*	***	*	***
Improved sulphitation in sugar extraction	*	***	*	***
Compact fluorescent lightbulbs	*	***	*	**
Low cost measures in chemicals	**	**	**	***
Traffic management	*	**	*	*
South Africa				
Cost effective freight improvements	*	***	**	*
CFLs for the domestic sector	*	***	*	*
Variable speed drives on HVAC fans in buildings	*	***	*	*
Lighting retrofits in commercial buildings	*	***	*	*
Efficient stoves in domestic sector	*	***	***	*
Retrofitting CFBC in the power sector	**	**	**	**

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Appendices

1 Introduction

This is the final report resulting from work undertaken for the Department for International Development on 'Prioritising Opportunities under the Clean Development Mechanism'. The aim of the project is to develop a methodology for identifying opportunities in developing countries under the Clean Development Mechanism (CDM), that provide both cost-effective greenhouse gas emissions reductions and contribute to promoting sustainable development. This latter area is of particular importance to DFID and the report pays particular attention to identifying the potential role of the CDM in funding projects that are in line with DFID's mission to promote global sustainability and reduce poverty.

The methodology has then been applied to case studies in China, India and South Africa to screen a wide range of greenhouse gas mitigation options and so identify those most likely to be attractive under the CDM. Work has also been undertaken to examine the scope for UK industry to be involved in the CDM and this has included discussions with UK companies.

Chapter 2 introduces the Clean Development Mechanism as defined by the Kyoto Protocol and outlines the current status of international negotiations to agree its operational detail. It then discusses some of the key design issues that remain to be resolved and considers how these could affect whether the CDM realises its potential for promoting a more sustainable development path in developing countries.

Chapter 3 then briefly reviews the experience gained with other project-based mechanisms, including the pilot phase of joint implementation, known as Activities Implemented Jointly and considers what lessons these have for the CDM.

In Chapter 4, the analytical methods and processes that can be used for selecting and analysing greenhouse gas mitigation options are discussed. Previous assessments of greenhouse gas mitigation options are described and based on the approaches used in these studies a generalised framework for such analyses is outlined. Each step of the framework is then discussed in more detail including the advantages and disadvantages of alternative approaches.

Chapter 5 presents an overview of the case studies, describing the particular circumstances of China, India and South Africa, the scope of the analysis and details of the screening methodology that has been used. Detailed results of these case studies are presented in the Appendices to this report and this chapter summarises the main results.

Chapter 6 then considers the potential involvement of the UK in the CDM and the benefits that it may have. The recent UK Climate Change Programme is briefly reviewed and an analysis is undertaken to examine what contribution the CDM could have in helping the UK meet its greenhouse gas commitments. As the CDM is aimed at bringing additional private sector finance into developing countries, the results of discussions with UK companies about their attitudes towards this mechanism are also summarised.

Finally, Chapter 7 draws some conclusions on the key factors that will determine the success of the CDM and identifies a portfolio of opportunities in the case study countries that are most likely to be attractive for CDM funding.

2 The Clean Development Mechanism of the Kyoto Protocol

2.1 INTRODUCTION

The December 1997 Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC 1997) specifies legally binding commitments on most industrialised countries to reduce a basket of six greenhouse gas emissions (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by 5.2 % compared to 1990 level by the period 2008 to 2012 (the first commitment period). Since, in the absence of these commitments, greenhouse gas emissions from industrialised countries would have increased substantially from 1990 levels by the commitment period, the actual reductions from business-as-usual implied by the Kyoto Protocol are substantially larger than 5.2 %. The International Energy Agency (IEA 1998) has calculated that, taking this growth into account, CO_2 emissions will need to be reduced by 3239 Mt or 19 % of their business-as-usual level in 2010 in order to meet the Kyoto commitments.

The Clean Development Mechanism (CDM) is contained in Article 12 of the Kyoto Protocol and is one of three flexibility mechanisms, now referred to as the Kyoto Mechanisms, included in the Protocol which allow greenhouse gas emissions reductions to be exchanged between countries. The purpose of all three mechanisms; joint implementation, emissions trading and the CDM is to allow countries with greenhouse gas emission reduction commitments under the Protocol to be able to meet these targets in the most cost-effective way. The unique feature of the CDM is that it is the only one of the Kyoto Mechanisms to involve both industrialised (Annex I) countries and developing countries in helping to meet the emission reduction objectives of the Protocol.

The CDM enables governments or private entities in industrialised countries to implement emission reduction projects in developing countries in order to meet their emission objectives. The industrialised countries then receive credit for these projects in the form of 'certified emission reductions' (CERs). The idea being that this arrangement could provide opportunities for industrialised countries to abate emissions at lower cost than could be achieved domestically. At the same time the developing country should benefit from new investment that increases economic productivity and which may reduce other local environmental problems.

Article 12 thus states three goals for the CDM:
- to assist in the achievement of sustainable development;
- to contribute to the ultimate objective of the Framework Convention; and
- to assist Annex I parties in complying with their emission reduction commitments.

Unlike the articles defining joint implementation and emissions trading, Article 12 makes no mention that activities carried out under the CDM must be supplemental to domestic action, although it does state that the mechanism is to *assist* Parties in meeting their targets. However, there is a requirement that reductions in emissions must be additional to any that would occur in the absence of the certified project activity. Furthermore, Parties can begin accruing CER credits in 2000 as opposed to joint implementation and emissions trading projects, which cannot be counted until the first commitment period in 2008.

Article 12 also establishes three bodies to oversee the CDM; the representatives of the Conference of the Parties serving as the Meeting of the Parties (CoP/MoP), an Executive Board established by the CoP/MoP and 'operational entities' to certify the emission reductions resulting from project activities.

The Protocol gives almost no guidance on how the CDM should work, or who should operate it. It merely states that it will be up to the CoP/MoP at its first session to 'elaborate modalities and procedures with the objective of ensuring transparency, efficiency and accountability through independent auditing and verification of project activities'. The CoP/MoP is also responsible for ensuring that proceeds from certified project activities are used to cover the administrative expenses of the mechanism and to assist developing countries, that are particular vulnerable to the effects of climate change, in meeting the costs of adaptation.

2.2 RULES AND MODALITIES FOR THE CDM

2.2.1 Progress to date

The year after agreement of the Kyoto Protocol, the fourth Conference of the Parties (CoP 4) was held in Buenos Aires in November 1998. At this meeting, the Parties decided on a work programme relating to the Kyoto Mechanisms that gave priority to the Clean Development Mechanism. This was adopted with a view to taking decisions on all the mechanisms at CoP-6 (to held in The Hague from 3 - 24 November 2000) relating to the following matters:

- Guidelines concerning provisions for joint implementation.
- Modalities and procedures for a CDM.
- Relevant principles, modalities, rules and guidelines, in particular for verification, reporting and accountability of emissions trading.

Following this meeting there have been ongoing discussions between the Parties, including a Technical Workshop held in April 1999, the meeting of the FCCC Subsidiary Bodies in June of that year and the fifth Conference of the Parties in Autumn 1999. Although no conclusions have yet been reached, and there are still differences between countries, it is appears that a consensus is starting to develop on how the CDM should operate.

This can be seen in the changing attitude of developing countries towards the use of the Kyoto Mechanisms. In Kyoto they formed a bloc (the Group of 77 and China) which was openly hostile to the introduction of market mechanisms, seeing them as a means for industrialised countries to avoid taking domestic action in order to meet their obligations under the Protocol. While still supporting the approach of the Climate Convention that industrial countries must take a lead, increasing numbers of developing countries now want to make progress on climate policy themselves and see the CDM in particular, as a vehicle for addressing climate change while promoting sustainable development.

2.3 OUTSTANDING ISSUES

A whole range of institutional, legal and technical issues need to be resolved before the CDM can become operational. The following sections highlight some of the areas that are of most relevance to the identification and selection of possible CDM projects and describe the current state of discussions as indicated by UNFCCC (1999).

2.3.1 Institutional issues

Executive Board

Article 12.4 of the Kyoto Protocol defines an Executive Board to be created which will supervise the CDM. It is generally envisaged that this role will be as the operational manager of the CDM under guidance from the CoP/MoP. The composition of this Board is in part likely to be determined by its function. For instance, if the Executive Board has a fair degree of autonomy, with only broad guidance from then CoP/MoP then there is likely to be keen interest from many Parties to have a seat. In this role, the Board may well operate at the policy level while leaving the operational entities to implement the details. If however, the CoP/MoP restricts the Board to operational activities, then it is more likely to undertake technical functions such as establishing CDM project criteria and guidelines. Under such a model the Board would have less power and so its composition is likely to favour technical experts over political representatives. Current proposals from Parties seem to favour the latter model, with a number of suggestions for a small, geographically equitable membership.

Operational entities

Article 12.5 defines operational entities having responsibility for certifying emissions reductions resulting from projects. It is likely that they will be supervised by the Executive Board and be accountable to the COP/MOP through the Board. Functions suggested for the operational entities include:

- Validating projects to ensure they meet the standards agreed by the COP/MOP.
- Verifying and certifying emission reductions (the latter task perhaps in conjunction with the Executive Board).
- Transferring a share of the proceeds to cover administrative expenses and to assist developing countries vulnerable to the adverse effects of climate change with meeting the costs of adaptation.

Discussions are still taking place as to whether these boards should be nationally appointed or whether independent organisations will be able to offer themselves in this role. In either case, strict standards will be needed to ensure that they operate in a credible, non-discriminatory and transparent manner.

2.3.2 Criteria for project selection

Article 12.5 states that for CDM project activities to be certified, climate benefits must be real, measurable and long term and the resulting emissions reductions must be additional to any that would occur in the absence of the certified project reduction. Other than these general principals no detailed criteria have yet been established and much of the discussion to date has been on how these principals should be interpreted.

Additionality

The Additionality criteria is probably the most important and has received most attention. Two types of additionality can be identified (Werksman 1998):

- *environmental additionality*: the CDM project activity brings about real, measurable and long-term environmental benefits related to the mitigation of climate change that would not have occurred in the absence of the project;
- *financial additionality*: the resources from the Annex B investor are additional to the financial obligations of the Annex I Party under the Convention, as well as to other current official development assistance.

In respect of environmental additionality, projects can be classified under one of three headings:

- abatement - projects that reduce greenhouse gas emissions currently being emitted, such as energy efficiency and fuel switching activities
- avoidance - projects which avoid emissions that would be emitted in the future if the project does not go ahead. Examples might include construction of a clean coal power plant rather than a conventional coal plant to meet the increasing demand for electricity.
- sequestration - these projects do not reduce anthropogenic emissions but rather increase the sinks available to absorb greenhouse gases. Projects in this category would include reforestation and afforestation. One particular issue here is that Article 12 does not specifically mention sinks, referring only to 'certified emission reductions' and so the eligibility of such projects within the CDM is still under discussion.

In each case, demonstrating whether a potential CDM project has yielded a net environmental benefit will require the construction of a counterfactual baseline, indicating the pattern of emissions that would result if the proposed project did not proceed. Clearly it may be easier to construct such a baseline for an abatement project, where the existing emission level is known, rather than in the case of an avoidance or sequestration project for which the profile of emissions in the absence of the proposed project may be more uncertain. The problems of baseline setting are discussed below in more detail.

The financial additionality criterion is particular important from the developing countries' perspective. This would ensure that financial transfers under the CDM are additional to other mechanisms such as the GEF. Without such a clause Annex I countries faced with the choice of financing the GEF and receiving global benefits, or financing the CDM and receiving CERs, could be tempted to put all their money into CDM. One way around this, suggested by Goldberg (1998), is that the GEF should concentrate on financing cutting edge projects utilising technology that might be deemed inappropriate for CDM projects.

A second issue relating to project financing concerns funds from the private sector. One of the most attractive types of investment could be for a company from an industrialised country to invest in energy efficiency improvements in a plant in a developing country in which it already has a stake. In this way the investor would not only get the benefit of CERs from the reduction in emissions of greenhouse gases but, in some cases, also the benefit of a significant reduction in operating costs. However, if the project reduces costs sufficiently, it could be argued that the investment would have been made even without the incentive of CERs and so could not be considered additional. It has therefore been suggested that any funding should be additional to that which would be undertaken as a commercially viable investment. However, the difficulties in deciding the definition of a commercially viable investment means that it is unlikely that any projects will be excluded from the CDM on the grounds that they have negative net costs. Indeed, the success of the CDM in attracting private sector investment may depend on allowing such investments.

Sustainability
A second important question is what criteria might be established for determining whether a project is contributing to sustainable development in the host countries. Neither the Kyoto Protocol nor the Climate Convention has a specific definition for sustainable development, but it is generally understood to involve a sustained increase in per capita 'well being' that does not degrade environmental systems in the process (Pearce 1998). The measurement of 'well being' typically covers indicators that go beyond GDP per capita to include measures of poverty reduction, educational achievement, health status, environmental improvement and human freedoms.

In the context of the CDM, projects could therefore contribute to the sustainability of the host nation by:
- providing positive gains to man-made capital e.g. through the transfer of technology or building infrastructure or improving the efficiency of the economy;
- improving environmental assets e.g. by preserving biodiversity, improving local air quality; or
- improving social and human capital through the creation of sustainable employment, the raising of living standards and the transfer of knowledge.

Other criteria have been suggested as being in keeping with the spirit of sustainable development are that the CDM should require that project benefits be shared with local communities and that it should maintain a balance between different types of project e.g. forestry and energy to ensure the promotion of sustainable development across all the key sectors.

Even if a set of indicators for sustainable development could be agreed upon, deciding whether they had been met is still likely to be problematic. It therefore looks most likely that it will be left to host countries to decide whether a particular project meets with its sustainable development needs, perhaps using some agreed guidelines. Given this flexible approach, it is not clear exactly how much sustainable development, the CDM will actually promote and this issue is considered further in Section 2.4.

2.3.3 Baselines
As explained above, the construction of appropriate counterfactual baselines is central to the success of the CDM. However, this process is far from simple and there are obvious advantages for both host and investors in overstating potential emissions reductions from a project. The host is more likely to find an investor if it produces suitable gains in terms of CERs and the investor will want to maximise the CER gained from a given level of investment.

Experience to date under Activities Implemented Jointly (AIJ) illustrates some of the problems with determining appropriate baselines. Chomitz (1998) highlights the example of an bilateral AIJ investment in Poland that sponsored the replacement of 68 coal-fired boilers with a central geothermal heating plant. The baseline assumed the indefinite use of the individual coal-fired boiler. A review team subsequently found that the local authorities had two back up plans in the event of the AIJ project not materialising: installation of a central modern coal-fired plant or installation of the geothermal plant with a lag of a couple of years. With hindsight it can be seen that the assumption of a baseline represented by the continued use of the existing coal-fired boilers was therefore clearly not valid in this case.

Michaelowa (1998) has discussed further inconsistencies and problems in baseline setting for AIJ projects. He notes the impact of government policy in Costa Rica, which is to phase out fossil fuel electricity production by 2001. This would mean that from this date the emissions baseline for all electricity generation projects would be zero, thus effectively ruling out this sector as a source of CDM projects. Another example cited is that of an AIJ project in Honduras involving the construction of a biomass-fired plant. The baseline for this project has been calculated on the assumption that the plant will displace a fossil fuel station. However, given that there is a severe excess demand for electricity in Honduras, the prospect of the fossil fuel plant being closed down seems unlikely.

To help ensure consistency across projects, a number of organisations have produced guidelines to help with baseline setting. For example the US Initiative on Joint Implementation guidelines (USIJI 1996) state that baselines have to be consistent with:

- prevailing standards of environmental protection in the host country;
- existing business practices within the particular sector of industry;
- trends and changes in these standards and practices.

A more comprehensive approach has been taken by the United Nations Industrial Development Organisation (UNIDO). UNIDO has been developing a software package, known as IDENTIFY, which it hopes will assist in the assessment of energy-efficiency and fuel switching projects in industry (UNIDO 1998). As well as providing a consistent framework for calculating emissions reductions, the model also calculates other important outputs such as the total cost of the project and the expected rate of return.

Even if a satisfactory set of guidelines could be devised and agreed which would allow project specific baselines to be constructed in a consistent manner, there remains the problem that the effort involved could be prohibitively expensive. Project developers would have to spend a significant amount of time and resources in gathering all the relevant information and regulators would be required to put in a similar amount of effort to review and approve the project applications. This is particularly likely to be a problem in some of the less developed countries, where problems due to the lack of data are likely to be acute. Alternative approaches are therefore being examined that would simplify baseline setting and additionality determination.

Under these methods simple rules would be developed for setting baselines and projects that produced emissions below these baselines would be considered to be additional and able to generate CERs. These approaches would result in reduced transaction costs for project developers and host and investor country governments. However, it would need to be shown that such simplifications would lead to credible baselines. The Centre for Clean Air Policy (CCAP 1998) has described three alternative approaches.

Technology matrix approach

A number of pre-defined default technologies would be considered to be the baseline technologies in a defined region and for a specified time. The emissions baseline would then equal the emissions rate for the specified technology. All technologies with lower greenhouse gas emissions would be considered to meet the additionality requirements. Periodically, new technologies that reached a certain level of take-up in the region would be added to the technology inventory and would no longer qualify as additional.

Benchmarking
Project emission baselines would be set based on emissions performance 'benchmark' rates that were determined with reference to criteria such as historic or projected sector specific emission intensity trends. All technologies that reduced emissions to below the benchmark levels could again be counted as additional and generate CERs. However, in contrast to the technology matrix approach emissions baselines could be set with reference to a mix of technologies, rather than a specific technology. Also the benchmarks could be forward looking or based upon the projected technological mix rather than the current capital stock. Countries would seek CoP/MoP or Executive Board approval for benchmarks they had developed.

Top down baselines
These are project baselines derived by the host government from a national baseline. Baselines could be set in terms of absolute emissions, or based on greenhouse gas emissions per unit of output so as not to restrict economic growth. Emissions would be allowed to grow in absolute terms as long as the carbon intensity of economic activity was falling. The national baseline would have to be set tightly enough so as to be acceptable to other Parties from a climate change perspective, but not so tight that the country involved could not claim credit for new ('additional') activities and initiatives or that its development needs were restricted.

Current discussions indicate that while some Parties are firmly of the opinion that project-by-project baselines (including standard baselines) should be used, others would prefer the top-down option. These different views, plus the problems of finding a method which is suitable for all potential CDM projects, make it likely that agreement on baselines will allow for a degree of flexibility and may leave scope for all of these different approaches to be used, depending on the circumstances.

2.3.4 Leakage
Whether project specific or simpler methods are used to calculate baselines, one important consideration is leakage. This refers to the problem whereby, in the absence of binding targets in developing countries, it is difficult to determine the net emission reduction effects of a specific CDM project since nationwide direct and indirect effects on emissions should really be included. Examples of leakage pathways cited by Parkinson (1998) include:

- substituting a polluting fuel which is then used elsewhere (e.g. since reduced demand leads to a fall in price);
- polluting processes being exported to countries without targets;
- changes in the life cycle of the fuel supply, increasing pollution outside of the project boundaries.

At one extreme, if leakage effects are thought to be significant they could justify an in-depth leakage assessment to model the national or even global effects of an individual mitigation project. However, for most projects it would probably either be sufficient to qualitatively identify the magnitude and direction of any leakages without attempting to explicitly include them in the assessment, or alternatively, to assign generic leakage coefficients relating to a particular type of project without conducting a project specific analysis.

In a study of an existing AIJ project, Begg (1998) reports on the comparison of the emissions reductions estimated using an energy systems model to capture both direct and indirect effects and the project level assessment for two electricity supply projects in the Czech Republic. This showed that there was little difference between the two approaches even when the projects were scaled up from a few MW to a few hundred MW. Leakage effects were therefore small in this case, although it is noted that this result could be specific to the project type, national circumstances or the type of national energy model used.

2.3.5 Supplementarity

Discussions on supplementarity have centred on whether there should be a limit on the extent to which credits from CDM projects can count towards Parties emission targets under the Kyoto Protocol. Developing countries, along with some EU Member States are concerned that those countries with targets should not use the flexibility mechanisms, including CDM, as a means of avoiding taking domestic action. Furthermore, the developing countries are concerned that the cheapest mitigation opportunities may be taken up under the CDM, leaving them having to rely on more expensive options in future years when they may be facing their own emission limits. To counteract these fears, it has been suggested that initially CERs generated by CDM projects should be limited. This would involve introducing a cap on the extent to which either just the CDM or all the Kyoto Mechanisms can be used by Annex I Parties to meet their commitments. Current proposals range from no cap to a limit of 25 % of countries' quantified limit. However, the 'umbrella' group of countries (USA, Canada, Japan, Russia, Australia, New Zealand, Iceland and Norway) oppose any such restriction to the use of the Kyoto Mechanisms on the grounds of economic efficiency.

2.4 THE CONTRIBUTION OF THE CLEAN DEVELOPMENT MECHANISM TO SUSTAINABLE DEVELOPMENT

By stimulating additional investment in developing countries, the CDM should be able to make a substantial contribution to sustainable development. However, as the preceding discussion on rules and modalities indicates, although the CDM is due for implementation in 2000, some of the important details about its operation have yet to be resolved. For example, it is not clear whether a cap will be placed on the use by industrialised countries of the Kyoto Mechanisms or whether activities involving carbon sequestration will be allowed under the CDM. With these uncertainties, it is difficult to be certain of just how large a mechanism the CDM will be and, equally important, the extent to which the non-greenhouse gas reduction benefits of economically attractive CDM projects will overlap with the sustainable development goals of host countries.

To date most studies that have looked at the potential size of the Clean Development Mechanism have involved a purely economic analysis. They have reached their conclusions based on modelling the need of industrialised countries to reduce greenhouse gas emissions below business-as-usual over the period 2008 to 2012 and the comparative costs of achieving these reductions through domestic action as compared with using the Kyoto Mechanisms.

The results of some of these studies are summarised in Table 2.1 and shows that estimates of the potential size of the CDM range from between 99 Mt of CO_2 and 2561 Mt of CO_2. This is equivalent to between 3 % and 80 % of the reductions that industrialised countries will need to achieve. The results also show that the value of emissions credits generated by the CDM is estimated to lie anywhere in the range between $1 billion and $26 billion. However, a number of experts, including the IEA (Baron 1999), have expressed doubts about the plausibility of some of the larger figures being derived on the basis of economic models. They point out that these are based on the assumption of perfect markets in which all Parties have full knowledge of their marginal abatement cost curves and that investments to generate CERs can be made without any loss of efficiency. In reality, the CDM will be a project-based mechanism and it is far from certain that sufficient projects could be implemented to generate thousands of millions of tonnes of emissions reductions, given the short time available before the first commitment period.

Table 2.1 Estimates of the size of the CDM (from Grubb 1999)

Study	Emission credits ($MtCO_2$)	Value of credits ($ billion)
Haites	99 - 2097	1-21
MIT	1001 - 2651	2.5-26
Austin	1456 - 1844	5.2-13
US Administration	367 - 689	4.2-7.9
RIIA	246 - 517	<5

Of more importance to developing countries, than the volume and value of the credits to Annex I countries, is what the CDM will imply for the magnitude and direction of investment flows to developing counties. This again is subject to considerable uncertainty. A report by the Adhoc Working Group on the CDM (UN 1999) suggests that the CDM could generate $5 to $10 billion of investment in developing countries per year. Compared to current overseas development aid flows estimated at $5 billion per year and foreign direct investment of $240 billion per year, the CDM could generate a substantial additional net investment by industrialised countries in the developing world. However, in some cases it may simply displace existing FDI, resulting in no change in the overall level of flows but perhaps changing the type of activity that is being funded to one that is hopefully more closely targeted at achieving sustainable development.

Furthermore, it is not certain how tightly the rules governing the sustainability criteria will be and hence whether projects selected under the CDM will unambiguously be considered as contributing to ‘real’ sustainable development. Technologies that may qualify for funding under the CDM as they reduce greenhouse gas emissions, but whose sustainability benefits have been questioned by some NGOs, include nuclear power and clean coal technology. Even amongst less controversial technologies, the use of renewables for rural electrification is likely to bring stronger sustainability benefits than the promotion of compact fluorescent lightbulbs. It is therefore currently an open question as to whether the most economically attractive projects under the CDM will also be those with the strongest sustainability benefits. This is an issue that is considered further in Chapter 5 of this report.

2.5 CONCLUSIONS

The Clean Development Mechanism has the potential to channel billions of pounds from industrialised to developing countries. As such it could fundamentally affect the development of these countries energy systems offering them access to the latest ‘clean’ technologies and thus promoting a more environmentally sustainable path for their economies.

However, before such a vision can be realised there are many issues regarding the operational arrangements of the CDM that need to be agreed. Whether and how these issues are resolved will determine the attractiveness of the CDM to both potential host countries and donor organisations. If the rules and modalities are not carefully thought out, with both climate and other environmental and social impacts considered, then the CDM will fail to meet its twin objectives of helping developing countries to achieve sustainable development and assisting industrialised countries is meeting their emission commitments.

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3 Experience with project-based mechanisms under the UNFCCC

3.1 INTRODUCTION

Chapter 2 noted some of the difficulties with setting baselines that have become apparent from the experience gained with the programme of Activities Implemented Jointly. This Chapter describes this, and other ongoing initiatives on projected-based mechanisms that are being undertaken within the context of the United Nations Framework for Climate Change and discusses what further lessons these have for the design and operation of the Clean Development Mechanism.

3.2 ACTIVITIES IMPLEMENTED JOINTLY

Prior to the Kyoto Protocol, joint implementation was a generic name given to a system whereby countries subject to the Climate Convention could invest in projects in other countries that were intended to reduce emissions of greenhouse gases. At COP1 in Berlin in June 1995 the Parties agreed to set a trial period for this mechanism with the name 'Activities Implemented Jointly' (AIJ). However, under this pilot phase there was to be no emissions crediting to the donor country.

The experience gained with AIJ will undoubtedly be useful a useful input to discussions about the design of the Clean Development Mechanism and later to those setting up projects to generate certified emission reductions (CERs). However, although superficially similar, Table 3.1 shows that AIJ and the CDM have important differences in their both their aims and implementation and these should be borne in mind when considering what lessons AIJ has for the CDM.

Table 3.1 Similarities and differences between AIJ and the CDM

Similarities	Differences
Both mechanisms are market-based for the transfer of financial and technological resources	CDM will have crediting, whereas this is not allowed under the AIJ pilot phase
Both rely on the fact that there are major differences in the abatement cost amongst parties	CDM has an explicit sustainable development focus that is not present in AIJ

By September 1999, 122 projects had been reported to the UNFCCC as being carried out under AIJ.[1] Table 3.2 shows the types of projects that have been undertaken and their impact on greenhouse gas emissions. So far no activities involving industrial processes, solvents, waste

[1] Information taken from UNFCCC (1999) Activities Implemented Jointly under the pilot phase: Issues to be addressed in the review of the pilot phase, including the third synthesis report on activities implemented jointly, FCCC/SB/1999/5.

disposal or bunker fuels have been reported. From Table 3.2 it can be seen that 75 % of the projects are in the areas of either renewable energy or energy efficiency. However, the largest contributor in terms of greenhouse gas emissions impact is from those involving forestry, which accounts for two-thirds of the total. It is worth noting that sinks is a category of project that is still subject to negotiation as far as the CDM is concerned and the evidence from the AIJ programme suggests that whether or not these are included could have an important impact on the overall size of the CDM.[2] Renewable energy and fugitive gas projects have also made important contributions to the overall emissions impact of AIJ, whereas the contribution from energy efficiency and fuel switching has been considerably smaller.

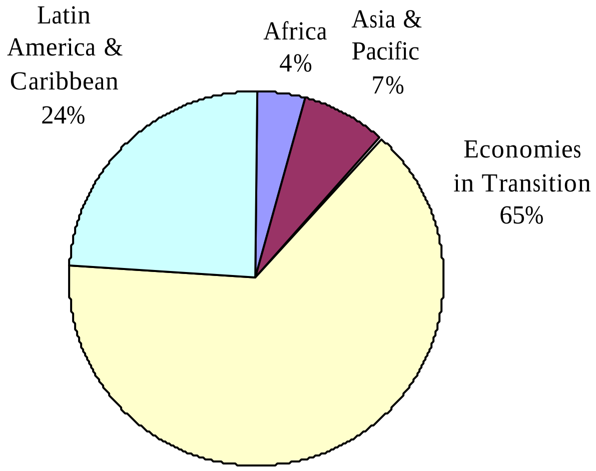
Table 3.2 Summary of AIJ projects by type of activity

Activity type	Number of activities*	GHG impact tCO_2 equiv.	Average GHG impact per project tCO_2 equiv.
Afforestation	1 (2)	292,728	292,728
Agriculture	2	3,068,588	1,534,294
Energy efficiency	40 (49)	7,674,540	191,864
Forest preservation, reforestation or restoration	12	140,890,371	11,740,864
Fuel switching	4 (7)	3,754,992	938,748
Fugitive gas capture	3 (4)	31,333,433	10,444,478
Renewable energy	46	30,120,003	654,783
Total	108 (122)	21,7134,655	2,010,506

**While the total number of projects is 122, only 108 project reports provided information on the GHG impact. Numbers in brackets indicate the total number of activities.*

Figure 3.1 shows the distribution of projects by region. This shows that nearly two-thirds of all projects are being carried in the Economies in Transition, with Latin America and the Caribbean accounting for a further 24 % and the Asia and Pacific region and Africa accounting for only 7% and 5 % of projects respectively.

Figure 3.1 Distribution of AIJ projects by region



[2] See discussion in Section 2.3.

Activities in the areas of energy efficiency, renewable energy, fuel switching and fugitive gases have been mainly implemented in EIT countries while forestry-related activities dominate in Latin America and the Caribbean. The few projects in Africa have involved providing renewable energy and energy efficiency.

As mentioned earlier, unlike the CDM, AIJ projects do not have an explicit focus to promote sustainable development. Nevertheless, there is an opportunity within the reporting requirement for sustainable development benefits to be noted and projects have been generally seen by countries as contributing national environmental, economic, social and development goals. Examples of environmental benefits cited by participants include reductions in emissions of non-greenhouse gases, such as nitrous oxides, sulphur oxides and particulates, fostering biodivesity, improving water and air quality and reducing erosion of hydrological resources. Among social and development benefits noted are the active involvement of local communities, the maintenance of natural heritage and historical sites, improved work environment, economic opportunities through the introduction of new technologies and the development of local production capacity through the involvement and/or establishment of local enterprises.

One further point worth noting is that the transaction costs associated with AIJ projects have often been high and this is one reason often given for why the programme has not been more successful in generating projects. A substantial element of these transaction costs are likely to be involved with validating and certifying project baselines and the later monitoring and verification of actual emissions savings and neither of these are likely to be strongly dependent on the level of greenhouse reduction achieved. The level of these costs will therefore impact more strongly on projects delivering smaller savings and, from Table 3.2, renewable and energy efficiency projects would appear to be particularly susceptible.

3.3 OTHER RELEVANT ACTIVITIES

3.3.1 World Bank Prototype Carbon Fund

The World Bank Prototype Carbon Fund (PCF) was formally established in July 1999.[3] Its aim is to mitigate climate change while promoting sustainable development, demonstrating the possibilities of public-private partnerships and offering a 'learning-by-doing' opportunity to its stakeholders.

The PCF is intended to achieve these aims by investing in projects that will produce 'high quality' greenhouse gas emission reductions that could be registered with UNFCCC for the purposes of the Kyoto Protocol. It is intended that the knowledge and experience gained through the PCF will be collected, analysed and disseminated to NGOs, governments, private sector interests, and any other stakeholders involved in the climate change negotiations. The PCF will be funded by both the public and private sectors and the World Bank aims to demonstrate how insights and experience from both sectors can be used to provide additional resources for promoting sustainable development and addressing global environmental concerns.

So far 22 private sector entities have signed non-binding Memoranda of Understanding, indicating their interest in participating in the PCF, including BP-Amoco from the UK. The governments of Finland, the Netherlands, Norway and Sweden are also supporting the project.

[3] Further details can be found at www.prototypecarbonfund.org

Emission reductions will be generated within the framework of JI and the CDM. The PCF will invest contributions made by companies and governments in projects designed to produce emission reductions fully consistent with the Kyoto Protocol and the emerging framework for JI and the CDM. Participants in the PCF, will receive a pro rata share of the emission reductions, verified and certified in accordance with agreements reached with the respective countries hosting the projects.

The intention is to maintain a balanced portfolio both geographically and covering a wide range of different technologies. Therefore approximately half of the investments will be made in Economies in Transition demonstrating JI, and half will be made in developing countries facilitating the CDM. The major emphasis will be placed on renewable energy. Two projects that have so far been identified and these involve solid waste management in Latvia and the development of locally based markets for environmental services provided by forest ecosystems in Costa Rica.

As a pilot activity, the PCF will not compete in any emission reductions market; it is restricted to US$150 million and is scheduled to terminate in 2012.

3.3.2 CDM dialogue hosted by the WBCSD Foundation for Business and Sustainable Development

A web-site has been set-up by the Foundation arm of the World Business Council for Sustainable Development to provide a structured and focused dialogue among all interested stakeholders on the practical aspects of designing and operating the CDM[4]. The intention is that the site should be used to promote learning and exchange of views on the different aspects of the CDM between the many stakeholders who will either be participants or beneficiaries.

Shell International is the founding sponsor of the website and is placing their projects on it for review and comment. In the future it is hoped that other companies will offer their projects for review. So far two Shell projects are on the web-site and these involve rural electrification in South Africa and a geothermal power station in South America. Table 3.3 shows the template that Shell has developed to assess potential projects for CDM eligibility and this type of format could well have wider applicability.

[4] The address of the web-site is www.foundation.no

Table 3.3 Summary of the Shell template for assessing potential CDM projects

Category	Description
1. Project description	This should include the nature of the project including project type, technology, location, size, fuel source, service area, operating efficiency, emission profile etc.
2. The CDM dimension	Why is the project potentially eligible to earn certified emission reductions credits under the CDM? Is it (a) consistent with local sustainable development in the host country and (b) less greenhouse gas intensive that what would have happened in the absence of the project?
3. Country context	A description of the sector in which the project would operate, including the projected energy supply and demand profile. The purpose being to enable a comparison to be made with what would have happened in the sector in the absence of the project.
4. Contribution to sustainable development	Explain how the project contributes to economic development, environmental protection and social development in the local or regional context.
5. What is the project displacing	More specific analysis on the current situation regarding what other energy source or project type is to be displaced by the new project.
6. What would have happened otherwise?	This section expands on the previous one by looking forward into the future under prevailing trends.
7. Would the project have happened anyway?	Would the investment have been made regardless of the value of the CERs?
8. Does the project result in real, measurable and long-term benefits?	Emphasis should be on the two key benefits of sustainable development and greenhouse gas emissions reductions.
9. Are the emissions reductions additional to any that would occur in the absence of the project?	Explain why the addition of this project will entail less greenhouse gas emissions that would have occurred in the absence of the project activity.
10. How many CERs will the project be entitled to?	This involves a quantitative calculation using information from 3,5,6 and 9 above.
11. How would the value of the CERs be applied?	The CERs that flow from the project will create an additional value stream to the project. Is the value of the CERs being used to offset costs at the margin allowing a larger project or higher market penetration? Has the country where the project is being developed indicated any interest or requirement to share in the value of the CERs generated?

3.4 LESSONS FOR THE CDM

The operation of these project-based mechanisms can provide some useful lessons for the development of CDM projects. In addition to the issues related to baseline setting that have already been discussed in Chapter 2, some of more important would seem to be that:

- Significant opportunities with low abatement costs exist in non-Annex I countries, with the cheaper projects tending to be in the areas of fugitive gas capture and energy efficiency.
- Forestry has been most prominent type of AIJ project in developing countries and this should be noted when considering whether sinks should be included within the CDM.
- There has been limited participation in AIJ by regions such as Africa and steps should therefore be taken to ensure that this is not repeated under the CDM.
- Emission credits would appear to be necessary to get the involvement of the private sector.
- High transaction costs can limit the attractiveness of project-based mechanisms and these can be particularly important for projects involving renewable energy and energy efficiency.
- The free flow of information between potential investors and hosts about project opportunities and methods of assessments is likely to be crucial to the success of the CDM.

4 Methods for assessing options to mitigate greenhouse gas emissions

4.1 INTRODUCTION

This Chapter addresses the analytical methods and processes that can be used for selecting and analysing greenhouse gas mitigation options. Based on a review of previous greenhouse gas mitigation studies it discusses a generic framework for such assessments and identifies the different levels at which such analyses can be made. Each element of the assessment framework is then discussed in more detail and the advantages and disadvantages of different approaches are noted. The objective of this analysis is to provide a background to the methods used in the country case studies described in Chapter 5 and to the analysis of the UK involvement in CDM, presented in Chapter 6.

4.2 CLIMATE COUNTRY STUDIES

The 1992 United Nations Framework Convention on Climate Change (UN 1992) committed Parties to the Convention to develop national programmes and measures to respond to climate change. To meet the need of developing countries to understand their emissions of greenhouse gases and to evaluate potential mitigation strategies a number of organisations have been working with these countries over the last 10 years in what are known as climate change country studies. Some of these studies have been concerned with drawing up inventories of greenhouse gas emissions for a particular year while others have projected emissions trends into the future. Many of the more recent projects have also considered possible abatement options.

In one of the earliest of the climate change country studies, funded by the US Environmental Protection Agency (EPA), the Lawrence Berkeley Laboratory used a disaggregated end-use approach to examine the long-term contribution of energy sources to carbon emissions in 12 developing countries (Sathaye 1991). A more comprehensive programme which also looked at the cost of abating greenhouse gases emissions was led by the United Nations Environment Programme's Collaborating Centre for Energy and the Environment (UNEP-CCEE) at the Risø National Laboratory in Denmark (UNEP 1992, 1994). Around the same time the Asian Development Bank (ADB) also completed a broad climate change study that, amongst other issues, evaluated mitigation options in several Asian countries (ADB 1994).

Following on from the US EPA study, the US Country Studies Program was initiated funded by 12 US government agencies (Sathaye 1994). This work is the largest climate change country studies activity and has supported over 50 projects in developing countries and those with economies in transition in order to assist them in their reporting requirements to the UNFCCC. The UNEP-CCEE has also undertaken another study supported by the Global Environmental Facility to further develop a framework for climate change mitigation assessment and this has been applied to eight developing countries and in two sub-regional studies (UNEP 1998a). The United Nations Development Programme and ADB are also currently funding a project focusing on 12 Asian countries called the Asia Least-Cost Greenhouse Gas Abatement Study or ALGAS (ADB

1998). There have also been a large number of bi-lateral country study activities including those involving Germany, Canada, the Netherlands and a number of Scandinavian countries.

Developing countries covered by previous climate country studies

Study	Developing countries
Sathaye (1991)	Brazil, India, China, Indonesia, South Korea, Mexico, Ghana, Sierra Leone, Nigeria, Argentina, Venezuela.
UNEP (1992, 1994)	Brazil, Venezuela, India, Thailand, Egypt, Senegal, Zimbabwe,
ADB (1994)	Pakistan, India, Sri Lanka, Bangladesh, Indonesia, Malaysia, Vietnam, Philippines.
Sathaye (1994) (US Country Studies)	Bangladesh, Bolivia, Botswana, Brazil, Chile, China, Ivory Coast, Ecuador, Egypt, Ethiopia, Fiji, Gambia, Indonesia, Kenya, Kiribati, Malawi, Marshall Islands, Mauritius, Mexico, Micronesia, Mongolia, Mozambique, Nepal, Nigeria, Peru, Philippines, Samoa, South Africa, Sri Lanka, Tanzania, Thailand, Uganda, Uruguay, Venezuela, Zambia, Zimbabwe.
UNEP (1998a)	Argentina, Ecuador, Peru, Indonesia, Mauritius, Senegal , Vietnam, Botswana, Tanzania, Zambia, Egypt, Jordan.
ADB (1998) (ALGAS)	Bangladesh, China, India, Indonesia, South Korea, Mongolia, Myanmar, Pakistan, Philippines, Thailand, Vietnam.

4.3 ANALYTICAL METHODS AND LEVELS OF ASSESSMENT

Through these various studies, methodologies appropriate for assessing the mitigation of greenhouse gas emissions have been developed and refined and practical experience gained in their use. Many of the approaches were reviewed by the Intergovernmental Panel on Climate Change in their Second Assessment Report. This categorised different levels at which these assessments were performed and alternative approaches that were appropriate (IPCC 1996a,b).

Matching methods to levels of assessment

Analytical method	Level of assessment		
	National	Sectoral	Project
Macroeconomic	×		
Decision analysis	×	×	×
Forecasting	×	×	
Costing analysis	×	×	×
Integrated planning		×	
Options identification			×
Options characterisation			×

4.3.1 Levels of assessment

National

At the national level, mitigation options are compared to determine their impact on the wider economy (land allocation, capital and foreign exchange demand, trade, employment, consumption and production) and other national interests or goals. In doing so, emphasis is often placed on the interrelationship between specific sectors and the overall economy. The types of methods used to assess and compare options at this level include pure macroeconomic models or modelling frameworks coupling sectoral models and macroeconomic models in order to capture the 'general equilibrium' effects throughout an economy caused by policies in a given sector.

Sectoral
The sectoral level involves analysis to compare the impacts of a number of projects in a sector or making structural changes to the system. Here the emphasis is on providing a consistent picture of a given sector within which to compare mitigation options. These sectoral analyses will usually take, as inputs, some macroeconomic parameters such as overall rate of growth. They provide a 'partial equilibrium' analysis as they do not capture the feedbacks between the behaviour of a sector and the overall economy.

Project
At the project level, the purpose of analysis is typically to identify and characterise specific project options in terms of their financial costs, technical performance and environmental characteristics etc. Characterisation of options is often based on techno-economic data and a given interest rate which can be used to construct technology cost curves. They can be calculated in the absence of any global scenario, but do not then provide a macroeconomic cost assessment unless fed into a coherent technical and economic framework. However, for comparison of alternative abatement options, such as that necessary for the clean development mechanism, it is necessary to work at this level of detail.

4.3.2 Analytical methods

Macroeconomic analysis
Macroeconomic analysis often is used to describe the current structure of an economy, to predict future economy-wide conditions and their impact on greenhouse gas emissions. Changes in these conditions, which could arise from taking actions to mitigate greenhouse gas emissions, can then be analysed.

Decision analysis
Decision analysis methods provide a structure for integrating sectoral and cross-sectoral greenhouse gas mitigation objectives with other national priorities. Basic decision analysis involves identifying potential options, measuring the potential impacts of those options (i.e., valuing the outcomes of various policy scenarios) and, based on this information, selecting the best options.

Forecasting
The acceptability of a mitigation strategy, program, or project is determined by calculating the difference between 'what would happen anyway' and 'what would happen if mitigation measures were undertaken'. The definition and development of these scenarios play a significant role in mitigation assessment. Forecasting is used here as a general term applied to methods used in developing time-dependent scenarios, such as econometric, time-series analysis and end-use forecasting models.

Costing analysis
Mitigation costing methods estimate and compare costs and benefits of mitigation options to identify the set of actions that maximises economic, social, and environmental benefits or minimises the analogous costs of reducing greenhouse gas emissions. Four basic costing

methods for ranking mitigation options are cost-benefit, cost-effectiveness, financial and supply curve analysis.

Integrated planning
Integrated planning approaches provide a structure for complex regional or sectoral assessments of multiple mitigation options. These methods typically are process or decision analytic-based and can be designed to produce both quantitative and qualitative results. A variety of quantitative methods can be used to support integrated planning.

Options identification
As many different mitigation options are available, there is a need to identify those options that are most likely to suit the needs and conditions of the particular country. Typically, options are screened against a series of criteria such as technological maturity, commercial availability, and technical performance. Information on potentially suitable options can come from case studies, literature reviews, general opportunity studies and the judgement of experts.

Options characterisation
Once data have been obtained on specific mitigation options, a system is needed for characterising options to ensure that the data obtained can provide usable information. A variety of methods are available to analysts, including cost curve analysis, estimates of tons of greenhouse gas avoided and engineering assessments.

These different analytical methods are certainly not mutually exclusive and frequently a number of different techniques will be combined together in a comprehensive mitigation study. The various elements of such studies are discussed further in the next section.

4.4 ELEMENTS OF A MITIGATION ASSESSMENT

From the various mitigation assessments that have been performed it is possible to identify a number of generic analytical elements which are usually applicable to studies of this type.

1. **Assessment of sources and sinks of greenhouse gases**: quantification of the emissions of greenhouse gas across and within sectors for preliminary identification of mitigation needs and priorities.

2. **Baseline development**: representing the increase in emissions expected as a result of economic growth, population increases and other factors over the relevant time period, without the imposition of extra mitigation policies or measures.

3. **Identification and characterisation of mitigation options**: Compiling an initial inventory of technologies/measures which can reduce emissions of greenhouse gases and gathering information on their costs, impact on energy consumption/carbon sequestration, other impacts etc.

4. **Techno-economic screening of mitigation options**: assessment of the cost and greenhouse gas emission reduction potential of each of the technologies/measures.

5. **Analysis of wider impacts of mitigation options**: these can include wider macro-economic impacts, socio-economic effects and local environmental implications and can be used to arrive at a short-list of appropriate climate mitigation technologies and measures.

6. **Identification of main implementation issues**: these may include arrangements for financial support, institutional capacity building, regulation policies etc.

7. **Treatment of uncertainty**: the sensitivity of results to uncertainties in data or alternative assumptions should be assessed to ensure the results are reliable and credible.

8. **Prioritisation of mitigation opportunities**: the final analytical step is to arrive at an approved list of prioritised mitigation opportunities.

Each of these steps is discussed in greater detail below.

4.4.1 Assessment of sources and sinks

For many developing countries work on quantifying current major sources and sinks of greenhouse gases is well underway. A comprehensive methodology has been developed by the Intergovernmental Panel on Climate Change (IPCC 1994) covering all the sectors (energy, industry, transportation, agriculture, forestry, other land use activities and waste management) with alternative levels of detail depending on the data available. Default values for parameters are also suggested. An inventory of this type is essential before any of the other steps in the assessment can be attempted.

4.4.2 Baseline Development

The impact of implementing climate mitigation options needs to be made in relation to a baseline projection of emissions which would occur in the absence of the technology or measure being adopted. The precise nature and extent of this baseline projection will depend on whether the assessment is being carried out at the project, sector or national level and baseline definitions need to be developed in accordance with these aggregation levels. However, UNEP (1997) identifies a number of considerations that are likely to be involved:

- activity projections for the main greenhouse gas emitting sectors and sinks
- technological development related to these sectors and sinks
- technological development related to the mitigation options
- market behaviour and implementation aspects related to mitigation options

A major difference between existing studies of greenhouse gas mitigation costs identified in IPCC (1996a) is the size and potential for so called ‘no-regrets’ options. This in turn is directly related to assumptions made when developing the baseline scenario about the efficiency of energy and other markets related to greenhouse gas emission sources and sinks. Since in determining the incremental costs of greenhouse gas abatement, more efficient technologies and practices are compared to the baseline assumptions then, if this baseline already contains the economically efficient uptake of these technologies and measures, additional uptake will necessarily incur net economic costs. However, if the baseline projection contains a sub-optimal allocation of resources, then it may be possible to reduce emissions while gaining a net economic benefit.

UNEP (1998a) highlights the fact that in developing countries many examples can be found of economically inefficient technologies being employed in all sectors of the economy. Thus comparing such technologies with new efficient mitigation projects will result in very low or negative mitigation costs. However, with the high economic growth rates expected for many developing countries in the future and the associated large-scale investment, careful consideration needs to be given to the size of such an efficiency gap in the longer term.

4.4.3 Identification and characterisation of mitigation options

All mitigation assessments need to identify technologies and measures relating to the most important future greenhouse gas emission sources and sinks, as identified under the baseline projections. Such mitigation options can be classified in a number of ways. IPCC (1996a) considers source-oriented measures (energy conservation and efficiency improvement, fossil fuel switching, renewable energy, nuclear energy) and sink-enhancement (capture and disposal of CO2, enhancing forest sinks). Whereas UNEP (1998a) disaggregates measures by time frame; with short term reduction options (energy efficiency improvements, forest management practices, small-scale renewable technologies, efficiency improvements in conventional power production) and long term reduction options (new power production technologies, large infrastructure projects, transportation policies).

A useful source of information from the perspective of developing countries is a survey of experiences, needs and opportunities undertaken by IVAM Research for the UNFCCC Subsidiary Body for Scientific and Technological Advice (Berkel 1997a). For each country covered, this work has identified on the basis of surveys the most important sectors, activities and technological opportunities for mitigating anthropogenic emissions of greenhouse gases, for enhancing sinks with a view to identify priority areas for climate-relevant technology transfer initiatives. However, the study also notes that so far developing countries have only surveyed the most important sectors and apparent technological options therein. There is still much to be done to assess mitigation needs in detail and to select the most appropriate environmentally sound practices for mitigation greenhouse gas emissions.

For each option identified a number of pieces of information will be required. In the energy sector, these are most likely to include:

- investment cost;
- fixed and variable operating and maintenance costs;
- expected life time;
- fuel prices;
- emission impacts;
- other costs and benefits.

A comprehensive mitigation assessment can therefore be very data intensive, requiring detailed information on perhaps hundreds of options. IPCC (1996c) notes that few industrialised countries have access to good quality data on all the parameters required and the problem is likely to be substantially more acute in developing countries. A balance will therefore probably need to be struck between the cost of data collection and the level of accuracy achieved (see treatment of uncertainty in Section 3.4.7).

4.4.4 Techno-economic screening of mitigation options

There are two broad approaches to the techno-economic screening of mitigation options. The first is a top-down method using a macroeconomic perspective in which mitigation costs are defined in terms of losses in key economic indicators such as output, gross domestic product etc. An important assumption in many top-down analyses is that the economy is in equilibrium, with all factors of production employed efficiently given the prevailing prices (Sathaye 1995). A direct result of these assumptions is that there can be no cost-effective mitigation options that have not already been adopted and therefore no potential for no-regrets actions to mitigate climate change. As discussed above, this type of approach is most suited to national level assessments where the impact across the economy is of particular importance and less emphasis is placed on understanding the details of mitigation at the sector and sub-sector level.

The alternative approach is a bottom-up assessment, which focuses on individual sectors and processes such as end-use energy consumption or specific forest management schemes. For each relevant source of greenhouse gas emissions, the bottom-up approach identifies possible mitigation options and attempts to identify the associated costs and the magnitude of the impact on greenhouse gas emissions. This approach can therefore allow for various market barriers which can prevent the uptake of measures that would be costs effective, either for a particular sector, or when assessed from a national perspective. This type of approach is most suited to the project or sectoral level of assessment and is discussed further below.

Costs of mitigation options

Mitigation costs, by definition, are assessed as the costs of implementing a mitigation strategy measure as the ‘incremental’ change in relation to a non-greenhouse gas policy case (UNEP 1998a). This approach is that endorsed by the FCCC (UN 1992) and has been implemented as a financing principle by the Global Environmental Facility (GEF 1994).

However, within this seemly simple principle there can be a number of different definitions of cost depending on the perspective being taken and the needs of the study. Financial costs measure the expenditure seen from the perspective of the implementing entity without any indirect positive or negative costs being taken into account. At the other extreme social costing reflects all the costs to society and includes valuing externalities and is often used as part of a cost-benefit or cost-effectiveness analysis.

A further parameter that needs to be given careful thought is the discount rate that is used to compare costs occurring at different periods in time. Again there are two approaches: an ethical approach based on what discount rates should be applied and a descriptive approach based on the rates actually being applied in that sector. The ethical approach leads to the selection of a discount rate that reflects the preference of society to investments in long term sustainability impacts associated with climate change mitigation. This discount rate is known as ‘the social rate of time preference’ and is generally low (around 3 % in real terms). On the other hand, the descriptive approach argues that the marginal rate of return on capital is the appropriate rate and this can lead to real discount rates that are much higher (above 20% in some cases). Lower discount rates generally favour environmental protection, whereas higher discount rates favour current consumption. So again, the context and aim of the mitigation assessment should be considered in deciding which approach to use.

Cost curves of greenhouse gas mitigation

A common way of representing the results of the cost-assessment for various mitigation options is to use a greenhouse gas emission reduction cost-curves or supply-curves. This approach was developed from the methodology of least cost integrated planning used for many year in electricity supply industry, particularly in the US (Jackson 1991). Applications in the UK include work by ETSU for the Nuclear Review (ETSU 1996). The methodology has also been applied to developing countries (ETSU (1997), UNEP (1994, 1998a), Sathaye (1995)).

The aim of the cost curve is to show the relationship between the costs of mitigation and the reduction in greenhouse gas emissions over a wide range of different supply and demand side options. The emission reductions can either be defined in relation to a base year (e.g. 1990 emissions) or in respect of a future baseline level of emissions.

The starting point for a cost curve construction is the individual mitigation options. The cost and mitigation potential of the various options can, however, be aggregated in different ways with different results. Some of the main methods for constructing the curves are outlined in Morthorst (1994):

- **the partial approach**: each mitigation option is evaluated separately with respect to both the increased costs and the greenhouse gas emission reduction. Results are then compared project by project in relation to the baseline. The projects are ranked according to the costs per unit of greenhouse gas reduction and a cost curve built up from these independent segments. A weakness of this approach is that no interdependence between the options is allowed in respect of either cost or mitigation potential. A results is that this type of approach will underestimate the costs of abatement.
- **the retrospective approach**: the first step is to rank the options separately as for the partial approach. In the next step, the most cost-effective project is included in the assessment and the incremental results compared to the reference case are calculated. The next most cost-effective project is included in the assessment, and a new calculation performed. At each step results are compared to the preceding ones and the so the next step on the cost curve is established. This approach has the advantage of taking into account the interdependence between a given project and very previous project on the cost curve. This approach tends to slightly underestimate the marginal costs of the most attractive options and slightly overestimate the marginal costs of the least attractive ones.
- **the integrated systems approach**: requires the existence of a well-defined reference case described within a fully developed energy system model. Points on the cost curve are then determined using the least cost solution for the total energy system, where in principle all demand and supply system parameters can vary. Models that have been used for this type of analysis include LEAP, MARKAL, MARKAL-MACRO, STAIR, ENPEP, CO-PATH, MESAP, ETB, MEDEE and ENERPLAN and the relative merits of each have been reviewed in IPCC (1996b). One general point that applies to this approach is that often it specifies a basket of greenhouse gas mitigation options and gives limited insight into the prioritising of individual technologies. However, work at ETSU has developed a simulation model, known as ENUSIM, which can be used to generate cost-abatement curves for industry based on identifying individual technologies and this is used to complement the DTI's econometric approach to forecasting UK CO_2 emissions. The US also uses a bottom-up simulation model (IDEAS) in its national forecasting.

4.4.5 Other impacts of mitigation options

Virtually every climate mitigation option being considered will produce some positive or negative impact that is outside of the scope the techno-economic assessment. In some cases these may not be measurable in physical units and only qualitative information will be available. Four broad classes of wider impacts can be identified (Berkel 1997b, UNEP 1998b, Sathaye 1995):

- **Macroeconomic impacts** - gross domestic product, employment, balance of trade
- **Socio-economic development** - consistency with national development goals, income distribution and poverty, skills transfer and training
- **Associated environmental impacts** - reduction of other pollutants, public health, land-use impacts e.g. with respect to natural habitats, land-use development
- **Sustainability** - long term sustainability and resource depletion/management

Many alternative methods have been developed for incorporating the costs and benefits of these other impacts into the assessment of mitigation options. One of the simplest is to prepare a matrix that provides a qualitative indication of the attractiveness of each option by marking it high, medium or low, as judged according to each criterion. The advantage of this method is that it is easy to perform and understand, but its value can be limited, since it says nothing about the importance of the various criteria in relation to one another.

A more refined method is to use multi-attribute analysis. Under this approach weights are assigned to the various attributes in order to measure and evaluate trade-offs between the different criteria. The determination of the 'attribute weights' is often the most difficult issue, but one way is to reveal preferences via questioning of decision-makers, stakeholders or experts. There are a number of stakeholder analysis tools, such as participatory rural appraisal, that have been developed and which are routinely applied to analyse issues connected with social development. Such approaches have the advantage of allowing local perspectives to be incorporated by including the appropriate participants in the process, although inevitably they are reliant on subjective judgement.

The most comprehensive and analytical approach would be to undertake a full external costing which places monetary values on all the impacts, thus enabling these external costs to be directly included in the techno-economic assessment of each option. However, whilst there has been much progress in developing external costing methodologies and values which are appropriate for industrialised countries, there are significant questions concerning the transferability of these results to the developing world.

4.4.6 Identification of main implementation issues

Implementing the projects and strategies selected through a mitigation assessment is a task in its own right, and therefore, one on which little emphasis is usually placed at the earlier stages. However, there are a number of key issues which if a least given some initial consideration as part of a mitigation assessment may help to influence the final selection of opportunities. IPCC (1996b) and Berkel (1997b) suggest that among the most important of these are:

- available programme delivery mechanisms and funding options;
- role of different institutions in implementation;
- capacity of the host country;
- co-ordination of cross sectoral strategies;
- commitment of other stakeholders.

4.4.7 Treatment of uncertainties

IPCC (1996c) notes that most analyses are affected by uncertainty due to poor data quality, rapidly changing economies and economies with little historical market data, etc. The report suggests that taking this uncertainty into account in estimating costs and impacts may be more practical than trying to achieve complete accuracy. This can be achieved by using ranges of values, rather than point estimates, by using expert judgement where good quantitative data is lacking and by undertaking sensitivity analyses (i.e.. by making an informed guess).

4.5 CONCLUSIONS ON THE PRIORITISATION OF MITIGATION OPPORTUNITIES

The previous discussions in this chapter have provided an overview of the approaches and the issues involved in the assessment of options for greenhouse gas mitigation. It is concluded that the final stage of the mitigation assessment should be to collate the information on each project and evaluate it against four broad headings

- **Mitigation potential**: to what extent and at what cost does the opportunity contribute to reducing emissions of greenhouse gases.
- **Socio-economic development potential**: to what extent does the opportunity contribute to achieving social and/or economic development objectives?
- **Environmental improvement**: to what extent does the opportunity contribute to a reduction of other prioritised national environmental problems (local air pollution, watershed management, protection of biodiversity, nature conservation etc.).
- **Anticipated commitment of stakeholders**: to what extent are the relevant stakeholders committed to undertake and finance the mitigation opportunity.

Such a comparative evaluation should generate a portfolio of prioritised mitigation opportunities that are cost-effective in reducing greenhouse gas emissions, may bring other positive socio-economic and environmental benefits and are acceptable to all the stakeholders involved.

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5 Country case studies on CDM opportunities

5.1 INTRODUCTION

Case studies to identify and prioritise potential opportunities appropriate to the Clean Development Mechanism have been carried out for China, India and South Africa and these are presented in Appendices 1 to 3. The results of these studies indicate the most promising types of greenhouse gas mitigation projects for funding under the CDM and show to what extent options that provide cost effective greenhouse gas abatement also contribute to sustainable development within the host countries. The information on the mitigation options will be used in Chapter 6 to perform an analysis to assess the potential scale of UK funding under the CDM in these countries.

The following sections provide background on the case study countries, explain the methodological approach and summarise the main results and conclusions.

5.2 CASE STUDY COUNTRY CIRCUMSTANCES

China, India and South Africa have been chosen for the case studies as, amongst non-Annex I countries (those eligible to host CDM projects), Table 5.1 shows that they are some of the largest emitters of greenhouse gas emissions. Together, the three countries currently account for about 15 % of total global greenhouse gas emissions and emissions of these gases are forecast to rise substantially in the future, so that by 2010 they could be responsible for emitting nearly 7 billion tonnes of CO_2.

Table 5.1 Non Annex I countries ranked by greenhouse gas emissions in 1990[5]

Rank	Country	Greenhouse gas emissions* ($ktCO_2$ equivalent)	GHG emissions intensity (tCO_2 equiv. per k$ GDP)
1	**China**	**2821614**	**1.4**
2	**India**	**999867**	**1.1**
3	Brazil	561513	0.7
4	Mexico	388758	0.7
5	**South Africa**	**364583**	**2.2**
6	Iran	351812	5.3
7	South Korea	288877	0.8
8	Kazakhstan	270145	3.0
9	Indonesia	268240	0.6
10	Venezuela	178365	1.3

*CO_2, CH_4 and N_2O

[5] Emissions data collated from a number of sources, including the US Country Studies Program, ALGAS project and National Communications. Economic data taken from the ENERDATA World Energy Database.

Not only are emissions from these countries large in absolute terms, but they also have economies which are greenhouse gas intensive as measured by total greenhouse gas emissions per unit of GDP. One consequence of this high intensity is that in the future, by employing more efficient and cleaner technologies, there may be considerable scope for these countries to limit the increases forecast in their greenhouse emissions.

Table 5.2 shows that one of the main reasons why the economies of China, India and South Africa exhibit such high greenhouse gas emissions intensities is because of their dependence on coal. In all the countries, coal accounts for over 50 % of total primary energy use from commercial fuels and in China and South Africa it is around 80 %. Clearly, all three countries will wish to continue to make use of this indigenous natural resource, but by using state-of-the-art technologies it may be possible to mitigate some of the future impact that coal use has on the environment.

Table 5.2 Summary of economic, energy and greenhouse gas emissions indicators for the case study countries (1990 data)[6]

		China	India	South Africa
GDP per capita ($)		348	314	3142
Contribution to GDP (%)				
	Industry	42	29	44
	Commercial and service	31	39	50
	Agriculture	27	31	6
Primary energy mix (%)				
	Coal	60.3	29.5	73.1
	Oil	13.5	16.7	13.0
	Gas	1.5	2.5	0.0
	Primary electricity (e.g. hydro and nuclear)	1.3	2.2	2.5
	Non-commercial fuels	23.5	49.0	11.3
Carbon intensity of primary fuel mix (tCO_2 per toe)		2.5	1.5	3.2
GHG emissions per capita (tCO_2 equiv.)		2.4	1.2	9.8
Emissions intensity (tCO_2 equiv. per k$ GDP)		1.41	1.10	2.19
Composition of greenhouse gas emissions (%)				
	CO_2	74.4	53.3	80.5
	CH_4	21.7	38.8	12.9
	N_2O	4.0	7.9	6.6

Apart from global climate change, there are other reasons why all three countries want to limit the environmental implications of fossil fuel use. For instance, emissions of sulphur dioxide, nitrogen oxides and particulates have already brought regional and local air pollution problems in all three countries. Average levels of particulates in major cities in China and India are more

[6] Energy, economic and demographic data taken from the ENERDATA World Energy Database.

than three times higher than those recommended by the World Health Organisation and in South Africa, the urban smog of Cape Town frequently obscures views of Table Mountain. Water quality is also suffering, with fifty per cent of rivers running through urban areas in China not meeting minimum water quality standards.

Although all three countries can be loosely termed ‘developing’ there are significant differences in wealth, with China and India being substantially poorer on a GDP per capita basis than South Africa. However, within South Africa there are enormous differences in the wealth between different sections of the population. The average income amongst the white population is close to that of western Europe, while the black community, which make up the bulk of the population, is little richer than the rest of sub-Saharan Africa. Other differences between the countries can be seen in the structure of their economies, with industry being the single largest sector in China and South Africa and agriculture still being significant in China and India.

These different national circumstances are reflected in the development priorities of the three countries. For instance, in its Long Term Plan to 2010, China aims to double its GDP while improving the productive efficiency of its industrial sector. Many of India’s development objectives give priority to the rural economy, while in South Africa increasing employment opportunities for the majority black population is a central goal.

Thus, while all three countries face a similar problem of trying to reduce the greenhouse gas intensity of their economies while promoting sustainable development, differences in the structure of the economy and in development priorities mean that the range of mitigation options available and their relative priority for funding under the CDM are likely to be country specific. This clearly needs to be taken into account in the CDM analyses.

5.3 SCOPE OF THE ANALYSIS

Under the Clean Development Mechanism, projects that lead to the reduction of any of the six greenhouse gases covered by the Kyoto Protocol may be eligible. However, the case studies undertaken as part of this project have focussed on identifying projects that abate or limit emissions of CO_2, as this is the most important greenhouse gas. Some options for abating emissions of the other greenhouse gases also exist, but these are generally less well characterised than for CO_2, both in terms of cost and effectiveness and this is particularly true for developing countries. For other sources, such as animals and soils, abatement is more complex and can often involve wider reform of agricultural practices.

CO_2 emissions are predominantly the result of energy production and use, with by far the most significant source being fuel combustion. Options to abate CO_2 emissions therefore need to be targeted at both energy supply and energy demand as shown in Table 5.3. The range of options available generally fall into two broad categories; improving the efficiency with which the current mix of energy is used (including reducing losses) in both supply and demand sectors or moving to the use of less carbon intensive fuels (including renewables).

On the supply side, examples of using fuel more efficiently include ‘clean’ coal technologies such as integrated gasification combined cycle, that have higher efficiencies than conventional pulverised coal plant or reducing losses from transmission and distribution. With respect to fuel switching, gas has a lower carbon content than coal and options such as nuclear and renewables produce no net CO_2 at their point of use.

On the demand side, more efficient devices such as compact fluorescent lightbulbs use around 25 % of the energy of conventional incandescent bulbs, whilst in a cogeneration plant more of the input fuel is turned into useable electricity and heat.
The particular sectors covered by the case studies for each country are:

- China: power supply, manufacturing industry and domestic/commercial
- India: power supply manufacturing industry, domestic and transport
- South Africa: power supply, industry (few options)[7], domestic, commercial and transport

Not all the options that have been considered in each of the sectors will necessarily be suitable for the CDM, but a broad coverage has been taken so that the role of the CDM within the wider context of the greenhouse gas emissions abatement can be better understood.

Table 5.3 Typical options for abating emissions of CO_2 from fuel combustion

Sector	Options
Power generation	Increasing efficiency of fossil fuel power stations
	Reducing losses from transmission and distribution
	Fuel switching to lower carbon fuels
	Increasing the use of renewable energy sources
Industry	Monitoring and targeting
	Improving the energy efficiency of processes
	Fuel switching to lower carbon fuels
	Co-generation
Residential	Improving end-use efficiency of devices
	Reducing energy loss
Commercial	Improving end-use efficiency of devices
	Introducing better controls
Transport	Improving the efficiency and operation of vehicles
	Using alternative fuels
	Managing transport demand and modal shifts

5.4 METHODOLOGICAL APPROACH

The approach to the case studies has been to identify for each country a wide range of CO_2 mitigation options covering both the energy supply and demand sectors. While it has not been possible to cover all possible abatement options, the case studies have attempted to address many of the most important options in each sector and to take account of the development priorities within the countries. Information on each of the options has been obtained from published data, together with the knowledge of local experts and ETSU staff based in the country. The

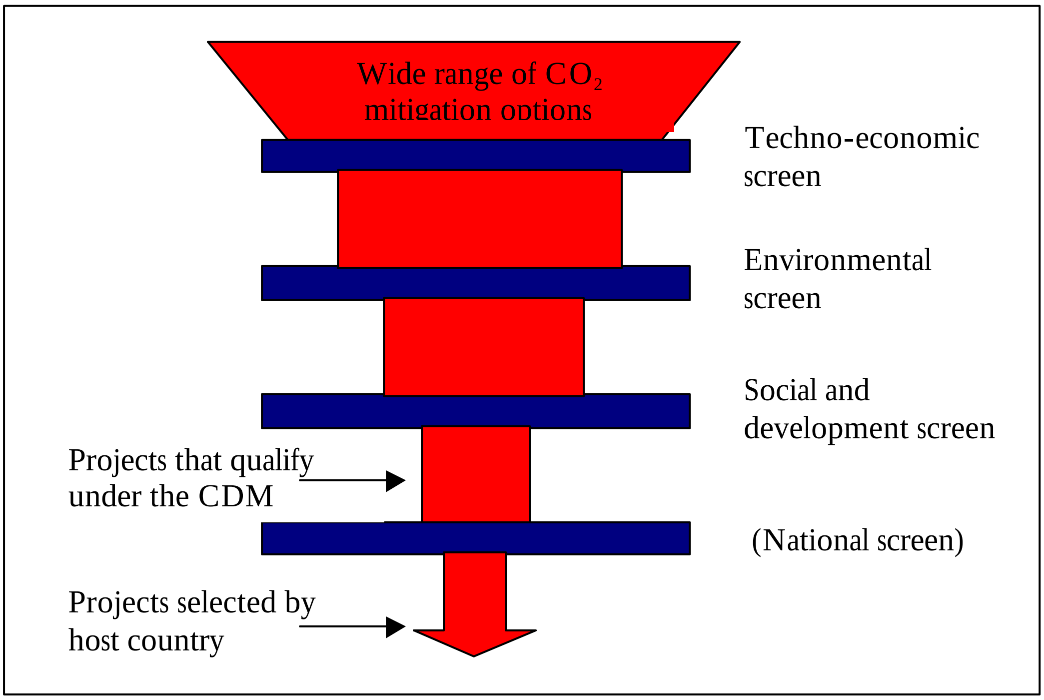
[7] South African manufacturing industry has a history that is very different from other countries due to its isolation during the apartheid era and is largely based on a coal/electric economy. Many of the processes used in South Africa differ from those found elsewhere and these, whilst sophisticated, are often unfamiliar. As a result, data on CO_2 mitigation options is relatively sparse and so only few options that are generally applicable have been considered. Also, development priorities in South Africa are particular focussed towards promoting social cohesion and this makes non-industrial measures more relevant.

approach has then been to subject each mitigation option to successive layers of screening in order to identify and prioritise those opportunities that are most suitable for funding under the CDM.[8] Figure 5.1 shows the screening layers that have been applied:

- techno-economic;
- environmental;
- social and development.

Finally, the results of the analysis have been checked with official policy statements and local experts to see whether the projects identified fit in with local development objectives.

Figure 5.1 Screening criteria for Clean Development Mechanism projects



5.4.1 Techno-economic screening

The methodology is based on a bottom-up engineering analysis of CO_2 savings opportunities because this is most appropriate to the level of detail required to identify potential CDM opportunities. For each measure being considered the following information has been collected:

- capital cost, lifetime, energy savings and any incidental costs or savings;
- the amount of each type of fuel used in the relevant technology or process;
- CO_2 emissions factors for each fuel, including electricity;
- the total installed capacity or output from the technology or process, thus determining the quantity of capital investment required to implement the measure for the entire sector.
- fuel prices appropriate to the relevant country;
- an appropriate discount rate;
- the US$ exchange rate, allowing all costs to be converted into dollars for international comparison.

[8] This type of methodology for screening CDM projects has been suggested by a number of different authors. For example see Hamwey R (1998) Practical approaches in the energy sector, reported in Goldemberg J (1998) Issues and options: The clean development mechanism.

Using this information, carbon dioxide emission reduction cost-curves or supply-curves are then created which plot the potential contribution of specific technologies as a function of their abatement cost (in monetary units per tonne of CO_2 saved). The retrospective approach (see Chapter 4) is used to take account of the interaction between abatement opportunities as the technologies are organised graphically in ascending cost order. The ‘cost effective’ level of technology contribution is the point at which the net abatement cost transfers from a negative to positive cost regime. Examples of national emissions reduction cost curves and the major technology contributions are presented in the case study appendices of this report. However, it should be noted that the costs of many of the abatement options that have been considered in the case studies are subject to a high degree of uncertainty and may often be site specific. As a consequence, the techno-economic assessment and resulting emission reduction cost curves should only be taken as indicative of the costs of these opportunities.

5.4.2 Environmental screening

As discussed in Chapter 2, an important component of sustainable development is the protection and enhancement of environmental assets. The environmental impacts of CDM projects can be at the local, regional and global level. Such impacts need to be measured relative to an existing business-as-usual project or other plausible baseline. CDM projects that reduce or limit greenhouse gas emissions, but have other unacceptable environmental impacts would then need to be excluded from the CDM. Conversely, projects that save greenhouse gas emissions and also provide other environmental benefits should, all other things being equal, get priority. In this study, it has only been possible to treat environmental impacts in a generalised way, without considering detailed project circumstances. However, when screening individual projects, impacts may often prove to be site specific. For instance, a location in which forests or lakes would be significantly affected by acid rain may not be appropriate for a clean coal plant, whereas it could be acceptable in a less sensitive location. The particular environmental criteria that have been used in the case studies are shown in Table 5.4. Clearly, this list is not exhaustive, but is indicative of the types of impacts that need to be considered.[9]

Table 5.4 Environmental criteria for assessing potential CDM projects

Impact	Description
Air quality	Will the project reduce emissions of other gases, reducing local/regional air pollution?
Water resources	Does the project lead to reduced water pollution/conservation of water resources.
Flood prevention	Will the project help with flood prevention?
Soil conservation	Does the project reduce soil degradation/loss?
Noise	Does the project lead to a reduction in noise?
Biodiversity	Does the project reduce loss/help improve biodiversity?

5.4.3 Social and development screening

CO_2 mitigation options may have positive or negative impacts on society and its development. Once again, the impact needs to be measured against a plausible baseline and any projects that

[9] The environmental and social and development criteria that have been used in this analysis are based on those suggested in WRI (1999) How much sustainable development can we expect from the Clean Development Mechanism.

have an unacceptable impact would need to be eliminated. Conversely, projects that, in addition to reducing CO_2, have beneficial impacts on society and its development may be given priority. For instance, a project that saves energy in industry by introducing the latest technology, may also lead to job losses as a result of increased automation. However, a project that introduced renewable energy generation into a rural area may be cheaper to operate than traditional fuels, such as kerosene for lighting and so help with poverty reduction. It might also bring health benefits by reducing indoor air pollution and also providing electricity for locally based industry, thus promoting rural development.

Table 5.5 Social and development criteria for assessing potential CDM projects

Impact	Description
Employment	Does the project lead to enhanced employment opportunities especially in key underdeveloped regions or among deprived social groups?
Rural development	Does the project have a positive impact on rural areas?
Poverty reduction	Are there positive equity impacts on the poorest sections of society?
Ability to target key groups	Can the project be targeted at particular disadvantaged groups in society e.g. women

A further important consideration in project selection is that relating to additionality and, as Chapter 2 indicates, this one area in which the rules likely to govern the CDM are particularly uncertain. Put in its simplest terms, the question is whether a project would have gone ahead even without the CDM and therefore whether the greenhouse gas emission reductions would have been achieved anyway. This is more likely to be an issue for those projects that appear to be economically attractive in their own right and as Section 2.3.4 discusses one suggestion is to exclude from the CDM any projects that have net negative costs. On the other hand the success of the CDM in attracting private sector investment may depend on allowing such investments. In the light of the current uncertainty surrounding the rules that may be adopted, no specific criteria for additionality has been included in this analysis. However, this is not to suggest that additionality will not be an important factor in determining the eligibility of greenhouse gas emission reduction projects under the CDM. Indeed, it could be possible for the Parties to agree criteria that would exclude from the CDM some of the more financially attractive investments identified by this analysis and this should be borne in mind when considering the results presented in the following section.

5.5 SUMMARY OF THE RESULTS

By applying these three layers of screening to CO_2 mitigation options identified in each case study country, a prioritised list of possible CDM projects has been developed. Tables showing these opportunities and ranking their techno-economic, environmental and social and development characteristics are shown in Tables 5.6 to 5.8. The main conclusions for each country are summarised below.

China

- Manufacturing industry offers the greatest scope for low cost CO_2 abatement, with many of the options generating substantial emissions savings. The sustainability benefits of abatement in manufacturing vary widely, but with careful selection it is possible to achieve cost effective greenhouse gas reduction while reducing other environmental burdens and promoting social and development objectives. Opportunities that can achieve these aims include low-density brick making, process improvements in steel-making, small-scale cement plant renovation and various low cost measures in low intensity sectors, such as textiles and engineering.

- Large emissions savings are also possible in the power sector, although the costs of these options are higher than in industry. Renewable energy from small hydro and biomass, in particular, brings with it many sustainability benefits, although the costs of achieving CO_2 reduction through these technologies is higher than using conventional technologies such as combined cycle gas turbines.
- In the domestic and commercial sectors, the potential for CO_2 savings is generally smaller and the options more expensive. However, the use of compact fluorescent lightbulbs to replace conventional incandescent lighting is highly cost effective, although the social and development impacts are likely to be small. More expensive as a CO_2 mitigation option is the introduction of biogas digesters, but these have the advantages of reducing both carbon dioxide and methane and bringing social and development benefits by providing a cheap source of clean fuel for cooking.

India

- The power sector offers the largest potential to reduce emissions of CO_2 and some of the options, most notably coal washing and combined cycle gas turbines for electricity generation can be highly cost-effective. The use of renewables, such as small hydro and wind, while being more expensive as a means of CO_2 reduction offer many sustainability benefits.
- Manufacturing industry is another sector in which many of the CO_2 mitigation options are cost effective, although the savings are typically smaller than in the power sector. However, the sustainability benefits associated with these opportunities can be substantial and particularly attractive options include low cost improvements in steel and cement-making and process improvements in sugar manufacturing.
- The domestic and transport sectors also offer cost-effective greenhouse mitigation options, albeit on a smaller scale than either the power sector or industry. These options can also have important sustainability benefits and improved cooking stoves (chulhas) have been identified as being particularly attractive.

South Africa

As industry has not been included to the same extent as China and India, the scope for CO_2 reduction that has been identified is lower. Nevertheless, cost effective opportunities exist in many areas including the domestic, commercial and transport sectors.

- In the domestic sector both the use of compact fluorescent lights (for grid connected households) and efficient stoves (targeted at non-grid connected households) are financially attractive, with the latter also having strong sustainability benefits.
- In the commercial buildings sector, the use of controllers on air conditioning fans and improved lighting systems are both shown to be cost-effective, although their contribution to sustainable development is not as strong as some of the domestic sector options.
- In commercial transport, improved driver training and better vehicle maintenance has been identified as highly cost effective.

- In the power sector, the most financially attractive option is to retrofit circulating fluidised bed combustion to the existing coal fired power stations, while in terms of sustainability both wind and biomass for electricity generation have strong co-benefits.

5.6 CONCLUSIONS

Overall, it was found that in all the case study countries, virtually every sector has opportunities for greenhouse gas mitigation that can also contribute to sustainable development, by providing environmental, social and development benefits. Furthermore, there was no clear positive or negative correlation between the cost-effectiveness of the projects that have been identified and their sustainability benefits. While some of the opportunities, such as renewables, which are traditionally associated with sustainable development can be an expensive way of achieving greenhouse gas emissions reductions, other options, notably involving energy efficiency in manufacturing industry have been shown to be both cost effective for emissions reduction and to make a positive contribution to sustainability. This is borne out by the fact that many of the options identified in the case studies as being appropriate for CDM funding have also been highlighted by the countries themselves as being important for their economic and social development.

Having identified the key mitigation opportunities in each of the case study countries that may be attractive under the CDM, Chapter 6 focuses on the possible role of UK involvement in this mechanism, through a more detailed cost and benefit analysis.

Table 5.6 Summary of the results for China

Opportunity	Mitigation cost	Greenhouse gas reduction potential	Other environmental benefits	Social and development benefits
Power				
Coal washing	**	***	**	*
CCGT	**	***	**	**
Large hydro	*	***	*	*
Small hydro	*	**	***	***
Nuclear	*	***	*	*
Biomass	*	*	**	***
Industry				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	***	**	*	**
Improved aluminium smelting	***	**	*	*
General steel process improvements	***	***	*	**
Continuous casting of steel	***	**	*	*
Ammonia plant renovation	***	**	*	***
Low cost improvements in glass	***	*	*	**
Hollow bricks	***	***	**	**
Low cost improvements in chemicals	***	**	*	**
Small scale cement plant renovation	***	**	**	**
Domestic and Commercial				
Lighting improvements	***	**	*	*
Biogas	**	**	***	***
Town gas	*	***	*	*
Thermally efficient homes	*	*	*	***
Solar water heaters	*	*	*	**
Efficient fridge	*	*	*	*

Table 5.7 Summary of the results for India

Opportunity	Mitigation cost	Greenhouse gas reduction potential	Other environmental benefits	Social and development benefits
Power				
CCGT	***	***	**	*
Coal washing	***	***	**	*
Small hydro	*	***	***	***
IGCC	*	***	**	*
Renovating existing coal plant	*	***	*	*
Wind	*	***	**	*
Industry				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	***	*	*	**
Manage capacity in paper & pulp	***	*	***	*
Improved grinding in cement	***	*	***	*
Low cost improvements in steel	***	**	***	**
Improved aluminium smelting	***	*	*	*
Continuous casting in steel	***	*	*	*
Control systems in cement	***	**	*	*
Fertiliser plant improvements	***	*	*	**
Process improvements in sugar	***	*	*	***
Bagasse cogeneration in sugar	***	**	**	*
Replace open hearths for steel	**	*	**	*
Low cost measures in chemicals	**	**	**	**
Domestic				
Improved chulhas	***	*	***	**
Compact fluorescent lightbulbs	***	*	*	*
Solar water heaters	*	*	**	*
Transport				
Driver training & better maintenance	***	*	*	*
Traffic management	**	*	*	**

Table 5.8 Summary of the results for South Africa

Opportunity	Mitigation cost	Greenhouse gas reduction potential	Other environmental benefits	Social and development benefits
Power				
Retrofitting CFBC	**	**	***	*
Wind	*	*	***	***
Biomass	*	*	**	***
Industry				
Co-generation	*	**	**	*
Boiler improvements	*	*	**	*
Domestic				
Compact fluorescent lightbulbs	***	*	*	*
Efficient stoves	***	*	***	**
Gas stoves	*	*	*	*
Solar water heaters	*	*	*	**
Thermally efficient housing	*	*	*	**
Solar home	*	*	**	***
Commercial				
VSD on fans	***	*	*	*
Lighting retrofit	***	*	*	*
Solar water heating	*	*	*	*
Transport				
Driver training & better maintenance	***	*	*	*
Improved traffic flow	*	*	*	*

6 UK involvement in the CDM

6.1 INTRODUCTION

This chapter examines the potential of the CDM for the UK private sector. It begins by outlining the UK's commitments to reduce greenhouse gases under the Kyoto Protocol and what policies are in place now. It then looks at the potential role of the CDM and discusses the views of business. At the outset of the project it was envisaged that a seminar would be held with the private sector to present results and canvass opinions. In practice, it has become clear that this would not be useful at this stage of CDM development and we have therefore preferred to carry out specific interviews and meetings with key UK companies. These are reported later in this chapter.

6.2 GREENHOUSE GAS EMISSIONS IN THE UK

Under the Kyoto Protocol of the United Nations Framework Convention on Climate Change the UK has agreed to reduce emissions of a basket of six greenhouse gas by 12.5 % of 1990 levels by the period 2008 to 2010. In addition, the government has a domestic target to reduce emissions of carbon dioxide, the most important greenhouse gas, by 20 % of 1990 levels by 2010.

New projections[10] from the DTI suggest that without any additional abatement measures, emissions of the basket of six greenhouse gas emissions will fall from 776 Mt CO_2 equivalent in 1990 to 701 Mt CO_2 equivalent in 2010 as shown in Table 6.1. Emissions of the most important greenhouse gas, carbon dioxide, are projected to fall less steeply from 616 Mt to 605 Mt.

Table 6.1 Projected emissions of greenhouse gases (Mt CO_2 equivalent)

	Baseline	**2000**	**2010**
Carbon dioxide	616.0	558.1	573.1
Methane	76.3	52.4	36.3
Nitrous oxide	66.0	43.3	43.6
Hydrofluorocarbons	15.0	7.0	14.3
Perfluorocarbons	1.1	0.7	0.4
Sulphur hexafluoride	1.1	1.5	1.5
Total greenhouse gas emissions	776.2	662.6	700.7
Change from baseline levels (6 gas basket)		-14.6 %	-13.4 %
Change from baseline levels (CO_2 only)		-9.4 %	-7.0 %

1990 is the baseline year for carbon dioxide, methane and nitrous oxide. 1995 is the baseline year for Hydrofluorocarbons, Perfluorocarbons and sulphur hexafluoride

[10] DTI (2000) Energy Projections for the UK, Working Paper, March 2000 and WS Atkins Ltd (2000) Projections of non-CO_2 greenhouse gases for the UK, March 2000.

These new projections take account of the likely impact of policies that have been introduced or announced since the signing of the Kyoto Protocol, including the effect of the climate change levy on business, the impact of fuel duty increase to 1999 and action to deliver a 10 % target for renewables in electricity generation. With the additional impact of these policies it is expected that emissions of the 6 gas basket of greenhouse emissions in 2010 will be about 13 % below their baseline levels which should therefore be just enough to meet the UK's Kyoto commitment.

To meet the Government's domestic goal for carbon dioxide, emissions would need to be reduced by 81 $MtCO_2$ from their projected level in 2010. This will therefore require additional domestic policies and measures to be implemented and may also offer the opportunity for the UK to make use of the Clean Development Mechanism to help meet its commitment.

6.3 DOMESTIC OPPORTUNITIES FOR EMISSIONS ABATEMENT

In the recently published draft UK climate change programme, the government has identified a large number of abatement opportunities across different sectors of the economy that could be used to achieve further reductions in carbon emissions by 2010. Table 6.2 summarises the savings that have been identified in each sector.

Table 6.2 Opportunities for greenhouse gas emissions abatement

Sector	Measures	Saving ($MtCO_2$)
Business	Climate Change Levy agreements, energy efficiency measures under the CCL, voluntary targets under domestic trading, new building regulations.	13.75 – 19.25
Domestic	Energy efficiency, replacement of community heating schemes, new Home Energy Efficiency Scheme, appliance standards and labelling.	14.7 – 19.4
Transport	Voluntary agreements on CO_2 from cars, changes to company car taxation and vehicle excise duty, implementation of integrated transport white paper.	26.8
Agriculture, forestry and land-use	Afforestation	2.2
Public	New targets for central government, schools and the NHS.	1.8
Total		64.5
Change from baseline levels (6-gas basket)		21.5 %
Change from baseline levels (CO_2 only)		17.5 %

The savings that have so far been identified and quantified are expected to reduce UK emissions of carbon dioxide to 17.5 % below 1990 levels by 2010. This leaves a further reduction of 2.5 % or 16.5 Mt in carbon dioxide emissions to meet the domestic goal. The Government has proposed that any credits generated through the Kyoto mechanisms should be included in the assessment of the UK's progress towards the domestic goal. One option to achieve the 'missing' 16.5 Mt of CO_2 would be through the Clean Development Mechanism and the following section presents an analysis of the optimum level of abatement that the UK could achieve through CDM activities with China, India and South Africa and identifies the least-cost mitigation options.

6.4 THE ROLE OF THE CDM IN MEETING THE UK'S CO_2 REDUCTION TARGET

6.4.1 Introduction

The earlier chapters have shown that evaluating the sustainable development impacts of CDM projects is integral to any assessment of the mechanism, since the CDM is intended to offer a broader view on developing countries interest than captured by a purely economic analysis. Nevertheless, the economics of CDM projects are also clearly important and so this analysis uses the cost-abatement curves developed as part of the case studies to evaluate the role of investment under the CDM as an option for meeting the UK's domestic CO_2 reduction target.

To do this, the following sections develop a methodology that aims to assess the likely scale of certified emission reduction (CER) purchases and the costs and cost benefits of CDM activity for the three countries studied (China, India and South Africa) and for certain important industrial sub-sectors (steel and cement). The analysis is performed for the year 2010 and so requires projecting a future baseline level of emissions. Whilst this is can only be approximated, it provides an analysis of the potential role until 2010 of the opportunities and costs under the CDM. Cost and targets are based on a 1990 base year.

6.4.2 Modelling assumptions

6.4.2.1 Technology opportunities.

Technology opportunities for China, India and South Africa have been identified from a range of sources and have been previously described in Chapter 5. The market size calculations also require the costs of greenhouse gas mitigation opportunities in the UK and these are based on specific manufacturing industry energy efficiency measures identified in previous studies by ETSU for the DETR.[11] This work was based on a wider technology study carried out for the publication of the Appraisal of UK Energy Research, Development, Demonstration and Dissemination, published in 1993. Since that work updates on technology opportunities and costs have been regularly carried out as part of the DETR Global Atmosphere Division study of forecasting of CO_2 emissions from UK manufacturing industry[12]. These studies assessed in detail all known opportunities for energy saving in UK manufacturing industry and provide costs, benefits and economic assessments for each of the technologies.

6.4.2.2 Investment and price assumptions

Investment criteria are important in determining the cost effectiveness of measures and are defined here in terms of the discount rate ascribed to capital investment and the period of amortisation of that investment. Since the analysis is attempting to identify cost effectiveness as

[11] ETSU (1996) Energy and Carbon Dioxide Saving Supply Curves for UK Manufacturing Industry, RYCA 18724001/Z/2, October 1996.

[12] The latest report is ETSU (2000) Industrial Sector Carbon Dioxide Emissions: Projections and Indicators for the UK, 1990-2020, ED 20616001/Z/4 Draft, February 2000.

perceived by the industrial sector in both the UK and the host countries, a 25% discount rate has been selected, with an amortisation period of typically 5 years.

The fuel price assumptions used in the calculations are shown in Table 6.3. Fuel prices for the UK have been taken from the Digest of UK Energy Statistics and for China, India and South Africa from IEA data [13].

Table 6.3 Fuel prices in $/GJ

	UK[14]	China	India	South Africa
Power				
Coal	-	1.00	1.36	0.26
LFO	-	4.52	4.90	-
HFO	-	2.95	3.14	3.65
Natural gas	-	2.12	2.42	-
Industry				
Coal	2.21	1.90	1.36	0.48
LFO	} 3.24	4.52	4.90	4.04
HFO		2.95	3.14	3.65
Natural gas	3.03	3.01	2.42	-
Electricity	16.4	12.13	18.67	8.44
Residential				
Coal	-	1.36	1.15	1.54
Diesel	-	5.59	4.90	4.44 (paraffin)
Natural gas	-		2.42	7.69 (LPG)
Kerosene	-			
Electricity	-	13.73	7.84	11.00
Transport				
Petrol	-	7.39	16.35	9.64
DERV	-	6.38	6.47	8.01

The common unit of currency adopted in the analysis is the US dollar and the following conversion factors have been assumed:

- £0.65 to the dollar
- 8.7 yuan to the dollar
- 43.6 rupees to the dollar
- 6.25 rands to the dollar

The technologies identified for China, India and South Africa, together with the carbon dioxide emissions cost curves have been described in the case studies and the information is summarised in Chapter 5 and the three case study Appendices. Key technologies and their contributions

[13] IEA (1999) World Energy Outlook, 1999 Insights, Looking at Energy Subsidies – Getting the prices Right.
[14] Only industrial fuel prices are considered for the UK because the analysis concentrates on the costs for the UK manufacturing sector.

and costs are also described. For each country and sub-sector there are a range of technologies which are cost effective (shown as a negative net annual cost of abatement), whilst others are not cost effective at the 25% discount rate assumed. According to economic theory, the opportunities presenting negative net costs should be adopted by manufacturers on the basis of them offering cost benefits. However, in practice there are evident barriers to the adoption of many cost-effective measures arising from issues such as:

- limits on borrowing requirements;
- other priorities within companies;
- risk and disturbance of existing production processes;
- other transaction costs, which are not included in normal cost analysis and which are difficult to identify.

For each sub-sector the cost and abatement data, together with the previous assumptions on fuel costs and emissions factors is sufficient to calculate the net annual cost of CO_2 emissions abatement in terms of per tonne CO_2 saved by investment in each of the mitigation options. The different technologies can then be ranked in order of cost per tonne of CO_2 saved by sub-sector and then aggregated to give the estimated relationship between carbon savings or energy, and cost to the UK manufacturing industry as a whole. The analysis by sub-sector also includes some opportunities for 'cross-cutting' technologies such as boilers, CHP and electrical drives. These technologies have only been selected in sectors where they offer relatively large opportunities for abatement as these are difficult to analyse and add significant complexity if applied across all sectors.

In the CDM analysis, whilst comparisons of abatement and costs are valuable at an aggregated industrial level, it is also important to make some assessment of individual sector CDM opportunities. This is because support for host countries under the CDM might find more support if common sectors become involved in the trade. In this way technical knowledge and verification issues are likely to be more easily addressed. Therefore, in addition to analyses carried out at national level, sector analysis for the steel and cement industries have also been performed, as these appear to offer some significant opportunities for CDM activity.

In the evaluation of the CDM, the cost supply curves developed for the UK and the three developing countries are used to provide a least cost solution from a composite of all national curves. The results are described in the following sections for the following scenarios:

- UK CDM activity in all three countries together (China, India and South Africa)
- UK CDM activity in China only – industrial and non-industrial measures
- UK CDM activity in India only – industrial and non-industrial measures
- UK CDM activity in South Africa only – non-industrial measures only
- CDM activity within the steel industries – in China and India
- CDM activity within the cement industries – in China and India.

The spreadsheet approach, which is used for the least cost analysis can also provide the following information:

- the domestic level of CO_2 reduction for the UK which minimises costs, once the CDM opportunities are also taken into account,

- the level of abatement undertaken in the host country in the least cost optimum i.e. the level of CDM activity,
- total net cost savings through the adoption of CDM,
- the avoided capital cost in the investor country (UK),
- the CDM CO_2 abatement value in $ per tonne of CO_2 which is calculated from the net cost savings (in the least cost solution) divided by the host country levels of abatement.

In carrying out the analysis of the CDM potential, a range of alternative abatement targets for the UK industrial sector have been considered, ranging from 10% abatement (of the 1990 sub-sectoral emissions level) up to a 30% requirement. In the following sections it will be shown that achieving these abatement levels at least cost requires different contributions from each of the host countries and from the various industrial sub-sectors as a direct result of their potential to supply different volumes of CO_2 abatement at differing costs.

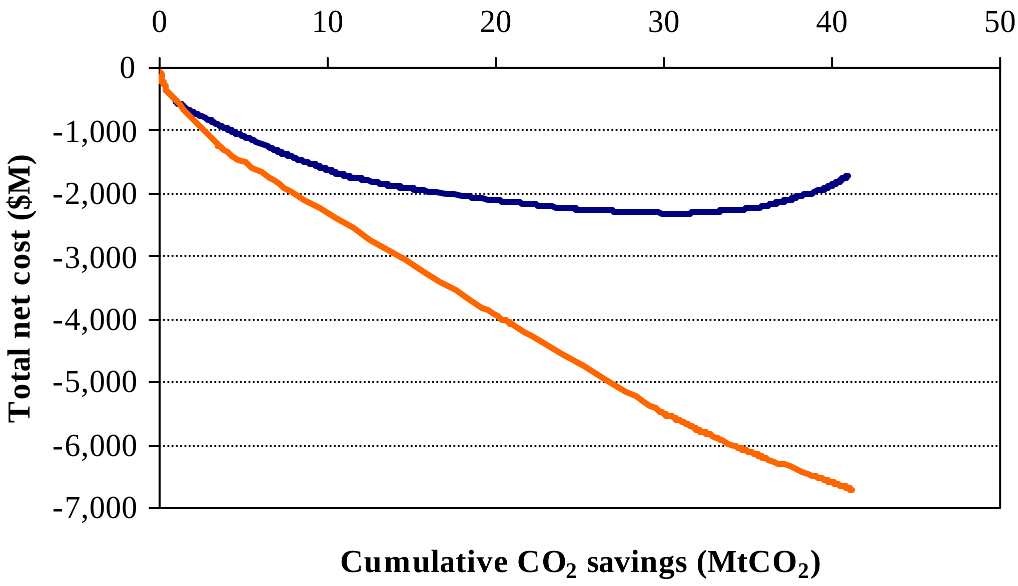
Each of the following sections describes the results of a particular CDM investment scenario, with the following information presented:

- A comparison of the total net costs for UK industry to meet the target CO_2 reductions with the net costs that could be achieved through using the CDM (defined as the least cost combination of abatement across the UK and the host countries for the countries/sectors being considered).
- A summary table describing the abatement levels and cost benefits resulting from specific country and sector CDM opportunities.

6.4.3 Analysis of CDM activity in all three countries

This analysis combines the opportunities in all three countries host countries with those in the UK and compares the aggregate costs of abatement with the costs of achieving the same level of reduction in the UK alone. Figure 6.1 shows curves of the total net costs of abatement as a function of increasing CO_2 savings requirements.

Figure 6.1 Comparison of total UK abatement costs with the least cost combination of UK domestic action and CDM activity in the three countries



For the UK (upper curve) total net costs are increasingly negative until around 30 Mt of CO_2 saving, after which total net costs begin to increase. This reflects the fact that up to around 30 Mt of CO_2 reduction can be achieved through mitigation opportunities in the UK that are cost effective (i.e. have negative total net costs). However, for a reduction in excess of 30 Mt CO_2, abatement costs become positive indicating that they are no longer cost effective at the discount rate of 25%. By comparison, the composite curve of all countries together (opportunities from the UK and the three developing countries) continues to be negative up to 40 Mt CO_2 saved and beyond.

In the UK the levels of abatement corresponding to 10%, 20% and 30% reduction targets are 13.6 Mt CO_2, 27.2 Mt CO_2 and 40.9 Mt CO_2 respectively. It is therefore apparent from Figure 6.1 that as the abatement targets increase, there is an increasing level of net cost savings to be achieved by using the CDM (given by the gap between the upper and lower curves). This is summarised in Table 6.4 where the cost benefits resulting from CDM activity at different CO_2 abatement levels are shown. The table also shows the least cost combination of abatement undertaken in the UK and that achieved through CDM activity.

Table 6.4 Analysis of CDM activity in all three countries - Industrial (China and India) and non-industrial measures (all three)

Required abatement level	10%	20%	30%
CO_2 saving required (Mt)	13.6	27.2	40.9
Least cost UK level (Mt)	1.1	1.7	10
CDM market (Mt)	12.5	25.5	30.9
Total net cost saving ($M)	1,037	2,790	4,950
UK capital cost savings ($M)	5,500	8,200	10,400
CDM CO_2 abatement value ($/t)	83	110	160

Even at a 10% abatement level it is evident that the least cost solution suggests a significant CDM market (12.5 Mt CO_2) which offers a total net cost benefit to the UK of over $1 billion and a UK capital cost saving of $5.5 billion. The value of the abatement achieved through the CDM, which is the total net cost benefit divided by the CDM level of abatement is $83 per tonne of CO_2. This is the figure that UK manufacturing would be prepared to pay for the CDM opportunity to obtain the net cost benefit derived. In practice, the market price of CDM opportunities could well be below this figure[15].

For a 20% abatement level, the CDM market doubles to 25.5 Mt CO_2 offering capital cost savings of $8.2 billion at an abatement value of $110 per tonne of CO_2. At 30% abatement, the least cost analysis suggests increased domestic action (increased to 10 Mt CO_2) with a CDM potential market of around 30 Mt CO_2. At this large level of abatement, avoided investment in the UK rises to $10.4 billion and the abatement value is $160 per tonne of CO_2.

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[15] The IEA reports that the value of CERs has been variously calculated at between $3.5 and $22 per tonnes of CO_2 (IEA (1999) Emissions Trading and the CDM: Resource transfers, project costs and investment incentives, report prepared for COP5, Nov 1999).

6.4.4 Analysis of separate CDM activity in China and India

Figure 6.2 provides a comparison of the total net costs of abatement in the UK (upper curve) with those available through separate investment in CDM opportunities in India (middle curve) and China (bottom curve). It is evident that net cost savings are likely to be higher through CDM arrangements with China and this is demonstrated in Tables 6.5 and 6.6 which summarises abatement levels and cost benefits resulting from undertaking CDM activity separately in the two countries.

With China there are significant net cost benefits resulting from a large CDM market, whereas with India it is evident that the CDM market is smaller (3.2 Mt compared with 12.5 Mt CO_2 at 10% abatement, 14 Mt compared with 22.4 Mt at 20% abatement, but growing to similar higher levels at a 30% abatement level).

At a 10% reduction level, the value of CO_2 abatement in India is higher than in China, whereas at higher abatement levels, values become lower in India. Capital cost savings at 10% and 20% reduction levels are higher from CDM activities in China, as would be expected, whereas by 30%, both countries offer similar levels of capital cost saving.

Figure 6.2. Comparison of total UK abatement costs with the least cost combination of UK domestic action and separate UK-China and UK-India CDM activity

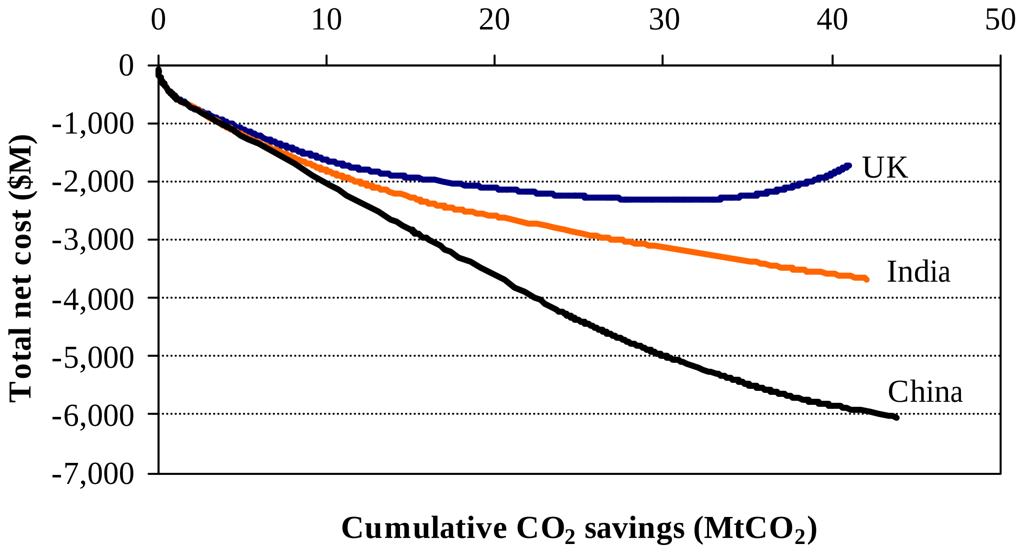


Table 6.5 Analysis of CDM activity in China - Industrial and non-industrial measures

Required abatement level	10%	20%	30%
CO_2 saving required (Mt)	13.6	27.2	40.9
Least cost UK level (Mt)	1.1	4.8	13.2
CDM market (Mt)	12.5	22.4	27.7
Total net cost saving ($M)	740	2,375	4,150
UK capital cost savings ($M)	5,500	6,600	9,510
CDM CO_2 abatement value ($/t)	60	106	150

Table 6.6 Analysis of CDM activity in India - Industrial and non-industrial measures

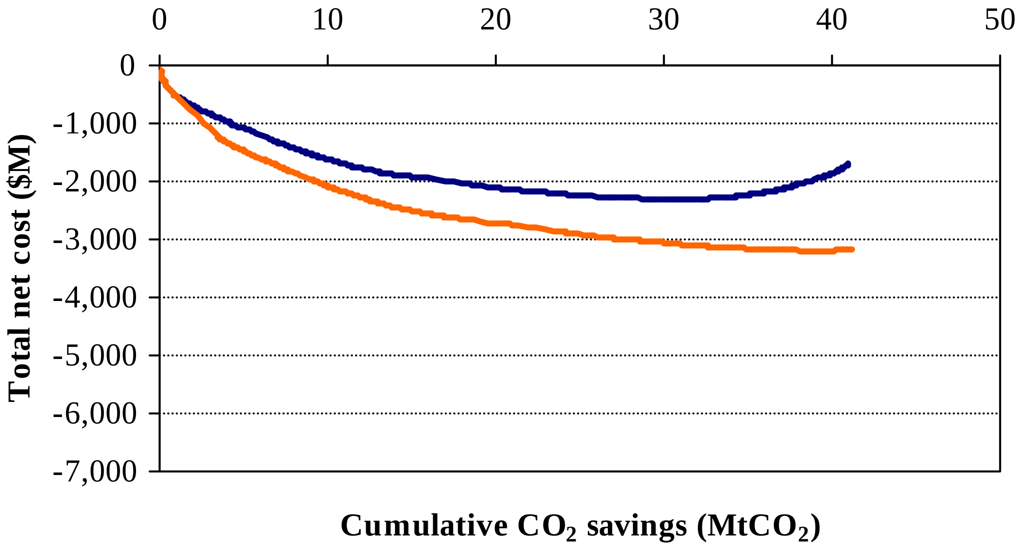
Required abatement level	10%	20%	30%
CO_2 saving required (Mt)	13.6	27.2	40.9
Least cost UK level (Mt)	10.4	13.2	15.1
CDM market (Mt)	3.2	14	25.8
Total net cost saving ($M)	290	708	1,880
UK capital cost savings ($M)	740	3,240	9,170
CDM CO_2 abatement value ($/t)	90	50	73

6.4.5 Analysis of CDM activity in South Africa

South African manufacturing industry has a history that is very different from other developed industries and is largely based on a coal/electric economy. Many of the processes used in South Africa differ from those found in Europe and these, whilst sophisticated, are often unfamiliar. As discussed in Chapter 5, for South Africa we have therefore decided to concentrate on non-industrial opportunities which also fits with the development aspirations of the country.

This tends to lead to less opportunity for CDM because of the often higher costs associated with non-industrial measures. Figure 6.3 shows a relatively smaller gap between total net costs of abatement in the UK and those possible from the least cost combination including South Africa.

Figure 6.3 Comparison of total UK abatement costs with the least cost combination of UK domestic action and CDM activity in South Africa



As an emissions reduction of 40 Mt CO_2 is reached the composite curve comprising of both the UK and South Africa is beginning to flatten and reverse, indicating that by this level the composite cost supply curve is moving into the non-cost effective region. As a result, Table 6.7 shows relatively low levels of CDM activity and smaller potential net cost saving benefits. Nevertheless, the CO_2 abatement values are relatively high suggesting that even at the low levels of activity implied, there are significant cost benefits to be obtained.

Table 6.7 Analysis of CDM activity in South Africa – Non-industrial measures only

Required abatement level	10%	20%	30%
CO_2 saving required (Mt)	13.6	27.2	40.9
Least cost UK level (Mt)	11.1	20.8	32.6
CDM market (Mt)	2.5	6.4	8.3
Total net cost saving ($M)	555	704	1,450
UK capital cost savings ($M)	540	1,870	4,850
CDM CO_2 abatement cost ($/t)	215	110	175

6.4.6 Analysis of CDM activity within the steel industries

This analysis has been carried out assuming a possible CDM arrangement between the UK steel industry and equivalent companies in India and China. Figure 6.4 shows that up to a 10% abatement level for the steel industry (3.3 Mt CO_2) net cost benefits of domestic action within the UK are higher than those to be obtained in either China or India. It is only above an abatement level of 4 Mt CO_2 that net cost savings are available from CDM investment in these countries.

Figure 6.4 Comparison of total UK abatement costs in the steel sector with the least cost combination of UK domestic action and CDM activity in the steel sectors of China and India

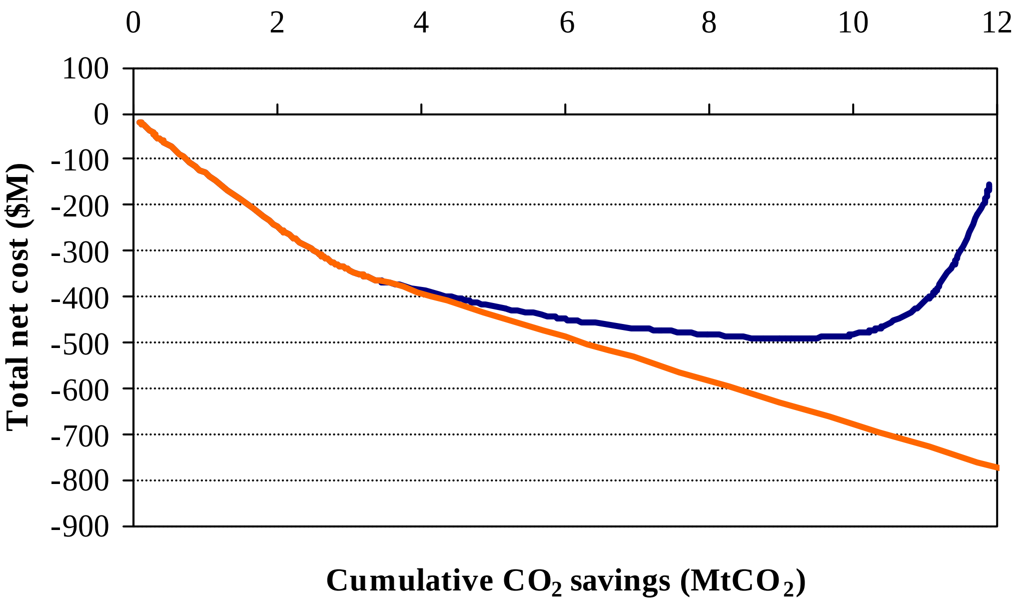


Table 6.8 shows that there is an optimum level of investment that can be made very cost effectively in the UK (up to around 3.4 Mt of abatement) after which it becomes more cost effective to invest in the CDM market. At a 20% abatement level there is an equal split between the use of domestic measures and those achieved through the CDM, with a resulting UK capital cost saving of around $235 million. By a 30% target, the UK capital cost saving is $500 million. The value of the abatement identified with the CDM is relatively low for the

steel industry compared with the other CDM scenarios, since there are still substantial cost-effective opportunities available in the UK.

Table 6.8 Analysis of CDM activity within steel industries (China and India)

Required abatement level	10%	20%	30%
CO_2 saving required (Mt)	3.3	6.6	9.9
Least cost UK level (Mt)	3.3	3.4	3.4
CDM market (Mt)	nil	3.2	6.5
Total net cost saving ($M)	nil	62	183
UK capital cost savings ($M)	nil	235	500
CDM CO_2 abatement value ($/t)	-	19	28

6.4.7 Analysis of CDM activity within the cement industries

The situation regarding the cement industry differs significantly from that of steel. This is shown in Figure 6.5 where it is evident that the actual cost of CO_2 abatement within the sector are high. At an abatement level of around 0.5 Mt CO_2 which is less than a 10% target, measures in the UK are becoming not cost effective and the CDM therefore offers a significant potential benefit to the industry.

Figure 6.5 Comparison of total UK abatement costs in the cement sector with the least cost combination of UK domestic action and CDM activity in the cement sectors of China and India

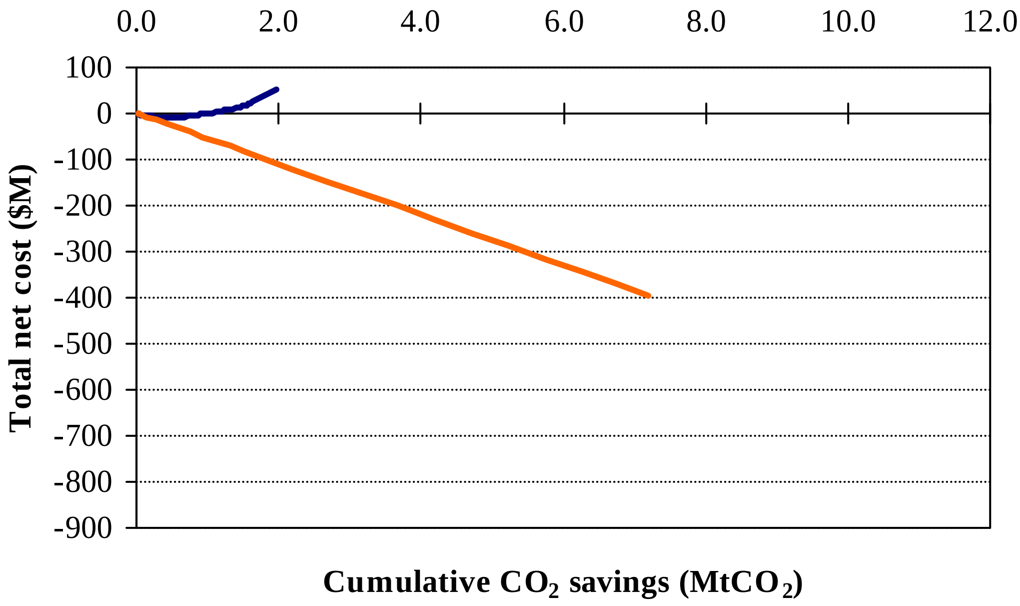


Table 6.9 shows that the least cost investment level for the UK is only 30 kt CO_2 and that abatement targets above this level are best achieved through CDM investments. The UK capital cost savings potential rises to $350 million at a 30% target and is approximately half this at a 20% level. The CDM abatement value rises from $40 per tonne of CO_2 at 10% abatement up to $67 per tonne of CO_2 at the 30% level. It is evident from this analysis that the UK cement industry should be considered a key sector for CDM activities.

Table 6.9 Analysis of CDM activity within cement industries (China and India)

Required abatement level	10%	20%	30%
CO_2 saving required (Mt)	0.6	1.2	1.8
Least cost UK level (Mt)	0.03	0.03	0.03
CDM market (Mt)	0.57	1.17	1.77
Total net cost saving ($M)	23	69	119
UK capital cost savings ($M)	40	160	355
CDM CO_2 abatement value ($/t)	40	59	67

6.4.8 Technology choices

The analysis using national sub-sectoral CO_2 cost-abatement curves allows the identification of the key technologies likely to be most important in the CDM. Tables 6.10 - 6.15 summarise these technologies using the same sets of CDM trading regimes as discussed previously:

- the UK seeks CDM opportunities across all three developing countries;
- separate CDM arrangements with China, India and South Africa;
- the steel and cement sectors in the UK seek to only invest in equivalent sectors in China and India.

In the tables a line is drawn under the groups of technologies identified in the actual least cost solutions (up to a 30% UK abatement level). However, in practice it is also important to identify the wider range of technologies which also show low abatement costs. The CDM market is unlikely only to focus on technologies offering the absolute least costs and since there are inherent variability in costs and abatement contributions, the analysis carried out here is indicative only. The tables also list (under the line) other technologies that are likely to be strong candidates for CDM investment, at least from an economic point of view.

Table 6.10 indicates that China tends to dominate opportunities and that low intensity sectors such as the textile industry, engineering and other miscellaneous industries (both China and India) offers a significant contribution. Paper manufacture is also likely to be significant. There are also some non-industrial measures such as freight management improvements in South Africa, improved domestic cooking stoves in India and commercial building improvements in China. The largest contributors are from Chinese light industries and Indian cement and steel plant measures.

Table 6.10 Key technologies for consideration from the analysis for all three countries

		CO_2 savings contribution (Mt)	Cumulative savings (Mt)	Typical abatement costs ($/t$CO_2$)
China and India	Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	16.6	16.6	-100 to -200
South Africa	Cost effective freight improvements	2.6	19.2	-250 to -300
China and India	Low cost paper and pulp measures and mill capacity management	10.9	30.1	-80 to -150
China	Aluminium smelting improvements	3.1	33.2	-95 to -100
China	Foundry processes improvements	1.3	34.5	-75
India	Improved domestic cooking stoves	1.8	36.3	-55
India	Improved grinding in cement	7.2	43.5	-55
China	Commercial building improvements	3.9	47.3	-50 to -55
India	Low cost steel plant measures	9.6	56.9	-45 to -50

Considering arrangements with China only (Table 6.11), additional opportunities such as further measures in the metals industry also arise. General steel plant improvements in China offer an enormous potential area for saving.

Table 6.11 Key technologies for consideration from the analysis for China

	CO_2 savings contribution (Mt)	Cumulative savings (Mt)	Typical abatement costs ($/t$CO_2$)
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	13.8	13.8	-150 to -200
Low cost paper and pulp measures	8.6	22.4	-150
Aluminium smelting improvements	3.1	25.5	-95 to -100
Foundry processes improvements	1.3	26.8	-75
Commercial building improvements	3.9	30.7	-50 to -55
Low cost non-ferrous measures	7.4	38.1	-40 to -45
General steel process improvements	~ 60	~ 100	-35 to -40

Technologies identified in the individual analysis of India are shown in Table 6.12. Additional opportunities from this scenario include raising aluminium smelting to international best practice standards, improved sugar extraction methods, measures in paper manufacturing including CHP and commercial freight transport handling improvements. Improve control systems in dry process cement manufacturing offer the single largest opportunity identified.

Table 6.12 Key technologies for consideration from the analysis for India

	CO_2 savings contribution (Mt)	Cumulative savings (Mt)	Typical abatement costs ($/t$CO_2$)
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	3.0	3.0	-50 to -200
Paper mills capacity management	2.3	5.3	-85
Improved domestic cooking stoves	1.8	7.0	-55
Improved grinding in cement	7.2	14.2	-55
Low cost steel plant measures	9.6	23.7	-45 to -50
Aluminium smelting best practice	1.4	25.0	-35 to 40
Improved sulphitation in sugar extraction	1.9	26.9	-35 to 40
Displaced bleaching in paper manufacture	0.35	27.4	-30 to -35
CHP in paper mills	0.5	27.9	-30
Cost effective freight improvements	6.6	34.5	-25
Continuous casting of steel	5.0	39.5	-22
Control systems in cement manufacture	~35	~75	-20

In considering CDM in South Africa (Table 6.13) the technology areas have been restricted to the non-industrial sectors. With this limitation on CDM activities, it has been possible to identify some of the more important non-industrial opportunities for the CDM. CFLs for the domestic sector make a significant contribution together with efficiency measures in domestic dwellings and in commercial buildings. Renovations to existing electricity generating plant makes the single largest contribution although in this case the abatement cost is positive indicating the measure to be not cost effective at the comparative investment criteria adopted.

Table 6.13 Technologies for consideration from the analysis for South Africa (non-industrial measures)

	CO_2 savings contribution (Mt)	Cumulative savings (Mt)	Typical abatement costs ($/t$CO_2$)
Cost effective freight improvements	2.6	2.6	-250 to -300
CFLs for the domestic sector	2.9	5.5	-35 to –40
Tank insulation in domestic dwellings	0.9	6.4	-35
Variable speed drives on buildings HVAC fans	0.12	6.5	-30
Lighting retrofits in commercial buildings	0.9	7.4	-20
Efficient stoves in domestic sector	0.9	8.3	-10
Renovating existing electricity plant	~21	~30	+21

Tables 6.14 and 6.15 consider analysis limited to the steel and cement industries separately. Investments in steel plants in India provide the least abatement costs and all other measures are found in China. Continuous casting plant developments in China make a significant contribution and are also relevant for India, although typical abatement costs in this country tend to be higher.

Table 6.14 Technologies for consideration from the analysis for the steel industry

		CO_2 savings contribution (Mt)	Cumulative savings (Mt)	Typical abatement costs ($/t$CO_2$)
India	Low cost steel plant measures	9.6	9.6	-45 to -50
China	Low cost steel plant measures	58.0	67.6	-35 to -40
China	Variable speed drives in steel plants	2.9	70.5	-35
China	Coal injection to blast furnace	0.4	70.9	-30
China	Continuous casting	~22	~90	-30

In the cement industry improvements in grinding and better control systems in India make a significant contribution. Opportunities in China are more towards kiln process improvements whereas in India many of the necessary conversions towards improved cement processes have already been made.

Table 6.15 Technologies for consideration from the analysis for the cement industry

		CO_2 savings contribution (Mt)	Cumulative savings (Mt)	Typical abatement costs ($/t$CO_2$)
India	Improved grinding -raw material and cement	7.2	7.2	-55
India	Control systems on dry process kilns	34.4	41.6	-20
China	Wet process comprehensive retrofits	2.8	44.4	-10 to -15
China	Vertical kiln renovation	14.3	58.7	-10 to -15
China	Lepol grate comprehensive retrofits	2.2	60.9	-10

6.4.9 Conclusions from the analysis

From the analysis of the possible role of the CDM as an option for abating UK emissions, the following conclusions can be drawn:

- By undertaking CDM activities in China, India and South Africa to reduce CO_2 emissions by 16.5 Mt CO_2 (to meet the gap between the current with policies and measures projections and the 20% domestic target), the UK could save over $6 billion of investment, that would be needed to achieve this level of abatement in the UK, while providing much needed investment in the three host countries.
- China offers the largest opportunities for investment under the CDM, although there are also substantial benefits to be gained by investing in India and, to a lesser extent, South Africa.
- Improvements to textile mills, light engineering and other miscellaneous small production plants offer highly cost effective investments mainly resulting from other benefits arising from process improvements such as quality and throughput increases.
- Improved grinding schemes and better control measures in the cement industry are important for India and offer highly cost effective investments. In China the requirements

are for more kiln process improvements which whilst cost effective are less so than measures in India.

- Metals processing offers opportunities for highly cost effective investment and large savings contributions. These are normally associated with simple measures such as boiler improvements, furnace upgrading and improved control and management. When CDM investment within just the steel sector is considered, the overall potential for CDM is relatively small. Nevertheless, restricting CDM activity to steel only, expands opportunities to be considered to include further process measures such as coal injection to blast furnaces and continuous casting.
- There are a range of low cost opportunities in paper and pulp manufacturing relevant to China and in India, paper mill capacity management is also an area for potential projects. In India other measures include increased CHP and the displacing of bleaching in paper manufacture.
- In the non-industrial areas more cost-effective freight handling improvements (South Africa) and improvements to the efficiency to the commercial buildings in both China and South Africa are important. Further measures outside of industry also include improved cooking stoves in India and a wider range of domestic measures in South Africa including hot water tank insulation and improved lighting.
- Chapter 5 has shown that many of these opportunities contribute to sustainable development in the host countries and so are likely to be highly relevant under the CDM. This is discussed in more detail in the conclusions of this report.

6.5 THE VIEWS OF UK INDUSTRY

Having undertaken the economic analysis of the potential for the CDM as an option to abate UK emissions, it is also clearly important to understand the perceptions of UK industry, as private sector involvement will be key to the success of the CDM.

In order to understand better the perspectives of UK industry towards this new opportunity, a survey was undertaken amongst a selection of large ‘blue-chip’ companies in the UK. The aim of the survey was to canvass opinion amongst industry as to their perception of the Kyoto Mechanisms in general and CDM in particular and their willingness or need to use such measures. The survey was carried out via face-to-face interviews during early 2000 and aimed at covering companies in a variety of different sectors. The list of companies included:

- Air Products Plc
- Anglian Water
- British Alcan
- British Airways
- Du Pont (UK) Ltd
- Glaxo Wellcome Plc
- National Power
- Pilkington Plc
- Shell International

These companies encompass both high and low energy intensity manufacturing industry as well as major energy companies and international transportation. Also represented are companies in sectors that are going to enter into negotiated agreements to reduce energy use and greenhouse gas emissions with the government and those in sectors not covered by the agreement. Some of the companies have their headquarters in the UK while others are subsidiaries of overseas organisations.

A set of questions used as the basis for the interview covered four main areas. These were:

- The companies awareness of the UK's commitment under the Kyoto Protocol and its domestic abatement goal and the options being considered by the government for achieving these targets.
- Which options for abatement the companies favoured.
- Whether they were familiar with the CDM and had considered it as an option for abatement.
- What the companies saw as the cost and barriers to participation in the CDM.
- What they saw as the benefits of participation.
- Whether they thought there were any risks in non-participation.

The following sections summarise the findings of the survey. In order to respect the confidentiality of individual companies, no views have been directly attributed.

6.5.1 Reducing UK emissions of greenhouse gases

All the companies were well informed about the commitments' placed upon the UK by the Kyoto Protocol and were aware of the government's domestic goal for carbon dioxide emissions. Seven of the companies were members of the CBI/ACBE emissions trading group that is working with the government to develop the rules for a pilot domestic emissions trading scheme. Five of the companies were in sectors that would be subject to negotiated agreements to reduce greenhouse gas emissions.

Over half the companies had tried to quantify the ways in which their organisation could reduce greenhouse gas emissions. The options that had most frequently been considered were energy efficiency programmes and targets and domestic emissions trading. Fewer had considered the role of international flexibility in meeting their targets, although in two cases, the companies were active participants in discussions surrounding the Kyoto mechanisms. Companies that were in sectors subject to negotiated agreements had generally considered the implications and a number of companies who would be subject to IPPC legislation had also begun to think about its likely effects on their use of energy.

A number of the companies had already introduced measures to abate emissions of greenhouse gases within their organisation, including one company with an internal trading system. One company stated that it would not formulate an internal plan for reduce emissions until it had some form of target to meet.

6.5.2 Options for abating greenhouse gas emissions

All companies had views on which options they preferred for reducing greenhouse gas emissions, with the overriding factor being the choice to achieve reductions in whatever way was most appropriate to their particular business circumstances. The most popular option was domestic emissions trading followed by negotiated agreements and then international flexibility mechanisms.

All companies said that economic factors would be most important in determining the mix of options they eventually used to abate emissions. Over half the companies also said that their environmental and social credibility/public relations would be a significant factor, three mentioned risk and one company said they would take account of synergies with other business aims.

6.5.3 Opportunities for future participation in the CDM

All the companies had heard of the CDM, but less than half felt that they fully understood the status of negotiations and the possible rules and modalities. The large energy producers and users were generally most well informed.

Around half the companies had considered the CDM generally within the possible range of abatement options, although little quantitative analysis had been undertaken. Most felt that there were too many outstanding issues that remained to be resolved for a clear picture of whether the CDM might be a preferred option for emissions abatement. A number of companies had given some thought as to the types of CDM project in which they might be interested in the future and one company was actively piloting CDM-type projects as part of its overall commitment to investing in society. These projects had been chosen because of their significant environmental and social benefits.

The majority of companies thought they were most likely to undertake CDM projects that were related to their core business and several mentioned undertaking projects in overseas plants that they wholly or partly owned. A couple of companies said that they might be willing to invest in projects offered to them, if the economics looked attractive. A number of companies were particularly interested in the potential role for suppliers of equipment under the CDM.

6.5.4 Costs and barriers to participation in the CDM

Since many of the companies had not got as far as thinking in detail about the CDM, most were only able to give some initial thoughts on the likely costs and barriers to their participation in the CDM. The major points that were noted included:

- Current uncertainty over the future rules and modalities of the CDM meaning that it was difficult to know what types of project might eventually qualify.
- The eventual form of the CDM would be important, with a high level of bureaucracy likely to discourage participation.
- The risk of not getting the credits either because of host country defaulting on the agreement or that they might have less ‘value’ than those generated by the other flexibility mechanisms due to inadequate verification procedures.
- A number of companies that might want to supply plant were concerned about losing control over the technology and competitors getting access to sensitive information.
- A couple of companies thought that CDM was unlikely to be any more risky than other business overseas, which they were well used to handling.

At a political level, several companies owned by US or Canadian organisations felt that, at the moment, the general anti-Kyoto feeling in North America could be an obstacle to their active participation in the CDM.

6.5.5 Direct benefits from participation in the CDM

All the companies expected that, depending on the precise form, the CDM could have a useful role in helping them to meet future emissions targets at least cost. A number of companies thought that there would be PR benefits from participating in the CDM, given the sustainability criteria, although some thought that domestic action was preferable from this point of view. Several companies saw the CDM as a chance for business development, e.g. by supplying plant or because it would make investments in particular markets more attractive. Depending on the rules, many of the companies thought there could be projects that would be viable even without considering the value of any emission credits.

6.5.6 Risks of non-participation

Two particular risks associated with non-participation identified were:

- Financial penalties for non-compliance under CCL, when participation in the CDM could have helped to achieve the targets; and
- The possibility that if action under the CDM was not taken in the short term, then the price of credits could rise as the first commitment period approaches.

6.5.7 Conclusions from the survey

The companies interviewed for this survey were generally positive about the clean development mechanism, subject to the current uncertainties being satisfactorily resolved. Most would need to carry out further analysis to look at their own costs of abatement and the costs of possible alternatives (emissions trading etc) before deciding what role there might be for investments under the CDM. It is clear that companies are unlikely to begin this process in earnest until they have a greenhouse gas emissions target against which any credits can be counted. Therefore, companies in sectors that have negotiated agreements under the Climate Change Levy, may be among the first to look seriously at possible CDM opportunities.

In assessing alternative projects suitable for CDM funding economic criteria will be most important, but many companies indicated that other factors, such as other environmental and social impacts, would also be considered. It is also likely that, at least initially, most companies will be looking to maximise benefits and minimise risks of participation in the CDM by investing as close to home as possible, either in a subsidiary or in an overseas company in which they have a stake. Finally, it should be noted that the companies covered by this survey may not be representative of UK business as a whole and, indeed, it is likely that smaller companies will be less well informed about climate change issues in general and the CDM in particular.

7 Conclusions and recommendations for further work

This report has presented the results of a project to develop a methodology for identifying opportunities in developing countries under the Clean Development Mechanism (CDM), that provide both cost-effective greenhouse gas emissions reductions and contribute to promoting sustainable development. The methodology has then been applied to case studies in China, India and South Africa to identify the most appropriate opportunities for funding under the CDM.

The main conclusions from this work are as follows:

- The Clean Development Mechanism has the potential to channel billions of pounds from industrialised to developing countries. As such it could fundamentally affect the development of these countries energy systems offering them access to the latest 'clean' technologies and thus promote a more environmentally sustainable path for their economies.
- However, the success of the CDM is dependent on agreeing a set of rules for its operation that balance the needs of investors for cost-effective greenhouse gas mitigation with the desire of developing countries for investment and technology that will stimulate economic and social development. Key issues that are important in this respect include the criteria for project selection (how strict are the additionality and sustainability criteria, whether sinks are allowed) and the methodologies used for determining baselines (whether transaction costs become excessive). In addition, evidence from previous project-based mechanisms suggests that there could be limited benefits for some of the poorest countries in the world such as those in Africa, unless steps are taken to specifically include these countries.
- The case studies show that there is no clear positive or negative correlation between the cost-effectiveness of the greenhouse gas mitigation opportunities that have been identified and their sustainability benefits. While some of the opportunities, such as renewables, which have clearly established sustainable development benefits can be an expensive way of achieving greenhouse gas emissions reductions, this study has shown that other options, most notably involving energy efficiency in manufacturing industry can be both financially attractive to potential investors and make a positive contribution to sustainability. Furthermore, the costs of many of the abatement options that have been considered in this study are subject to a high degree of uncertainty and may often be site specific and so the results of the techno-economic assessment should only be taken as indicative of the costs of these opportunities.
- Table 7.1 shows a list of greenhouse gas mitigation opportunities that have been identified as being most relevant for CDM funding. They have been selected both because they offer very cost-effective greenhouse gas mitigation (shown by three stars against typical abatement costs) and have acceptable social and development implications or because they are slightly more expensive, but have strong sustainability benefits (two or three stars in this category). Those opportunities highlighted in bold score well against both criteria. Amongst the most attractive opportunities that have been identified are low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries (China and India),

CCGT plant for electricity generation and biogas digesters in the domestic sector (China), improved cooking stoves in the domestic sector (India and South Africa), low cost improvements to steel plants (India) and freight distribution and management improvements (South Africa). However, it should be noted that depending on the additionality and sustainability criteria that are finally agreed by the international community, some of opportunities identified in this analysis could be excluded from the CDM.

- In the context of the UK's commitment to reduce emissions of greenhouse gases it has been shown that the CDM can be a cost-effective element of the climate change programme, helping to bridge the 16.5 Mt CO_2 gap between what existing policies and measures will deliver and the government's domestic target for CO_2 reduction. This would enable the UK to offset up to $6 billion of investment associated achieving the same level of abatement in the UK, while providing an important source of funding for developing countries.
- These results were backed-up by the findings from a survey of UK industry which showed that many companies believe the CDM could have a useful role in helping them to make greenhouse gas emission reductions in the most cost-effective way, while also noting that social and development factors would be a consideration in project selection.

In the light of the conclusions of this project, the following recommendations are made to enable both developing countries and the UK to get maximum benefit from the opportunities offered by the CDM.

- While greenhouse gas abatement options in China and India are relatively well characterised, the case study of South Africa has confirmed the belief that this is not the case for many other developing countries. In order for these countries to be able to take full advantage of the CDM, they will need the capacity to identify appropriate CDM opportunities and possibly to set up a CDM office to liase with potential investors. Evidence from the AIJ programme suggests that, without such capabilities, many poorer countries will be at a considerable disadvantage and risk being overlooked altogether. It is therefore suggested that one possible area for further activities would be to work with governments and experts in a number of developing countries to develop the institutional and technical capacity necessary to identify and promote opportunities that are in line with national development needs and are suitable for CDM funding. The precise choice of countries would need examined more closely, but it is suggested that countries in Africa, along with many small island states, could perhaps benefit the most from such activities.
- Discussions with UK industry have revealed the desire of companies for further information from government on the role and requirements of the CDM. One way of achieving this would be to develop closer liaisons with other government initiative and in particular DETR activities such as the web-site 'Business Opportunities and the Kyoto Mechanisms (http://www.environment.detr.gov.uk/climateoffice/index.htm) to provide further information to UK business on the scale of opportunities and priority areas for CDM activities. For instance, a summary of this report could be placed on this web-site.
- After COP 6 the rules and modalities for the CDM should be clearer and so it would be timely to organise a DFID/DETR/DTI sponsored conference, in perhaps December 2000, to promote the potential role of the CDM in helping to promote DFID's developmental objectives and to assist UK industry in meeting its current and future greenhouse gas emission targets.

Prioritised CDM opportunities in China, India and South Africa

	CO_2 abatement	Typical abatement costs	Contribution to sustainable development	Interest to UK companies
China				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	**	***	**	**
Low cost paper and pulp measures	*	***	*	***
Aluminium smelting improvements	*	***	*	***
Foundry processes improvements	*	***	*	***
Commercial building improvements	*	***	*	**
Domestic and commercial lighting improvements	**	***	*	**
CCGT	***	**	**	***
Biogas digesters in the domestic sector	**	**	***	*
India				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	*	***	**	**
Paper mills capacity management	*	***	*	*
Improved domestic cooking stoves	*	***	***	*
Improved grinding in cement	*	***	*	***
Low cost steel plant measures	**	***	**	***
Aluminium smelting best practice	*	***	*	***
Improved sulphitation in sugar extraction	*	***	*	***
Compact fluorescent lightbulbs	*	***	*	**
Low cost measures in chemicals	**	**	**	***
Traffic management	*	**	*	*
South Africa				
Cost effective freight improvements	*	***	**	*
CFLs for the domestic sector	*	***	*	*
Variable speed drives on HVAC fans in buildings	*	***	*	*
Lighting retrofits in commercial buildings	*	***	*	*
Efficient stoves in domestic sector	*	***	***	*
Retrofitting CFBC in the power sector	**	**	**	**

Appendices

CONTENTS

Appendix 1
China case study

China Case Study

INTRODUCTION

This case study describes the work undertaken to identify and prioritise greenhouse gas mitigation opportunities in China that might be suitable for funding under the Clean Development Mechanism. It is divided into the following sections:

- Country profile
- National development objectives
- Energy and greenhouse gas emissions
- Chinese attitudes towards the CDM
- Opportunities for CO_2 mitigation
- Techno-economic screening of mitigation options
- Environmental, social and development screening of mitigation options
- Prioritisation of potential CDM opportunities

COUNTRY PROFILE

Population

China is the most populous country in the world and the population has grown from about 542 million in 1949 to an estimated 1,210 million in 1995. In recent years the Chinese government has put in place a vigorous family planning policy and as a result the birth rate has declined to 1.71%. It is expected that the population will stabilise at around 1,500 million in the middle of the 21st century.

Economy

China's economy has grown rapidly in recent years, averaging an annual growth rate of 12 % during the Eighth Five Year Plan (1990 – 1995) so that by 1995 China was the seventh largest economy in the world, with an estimated gross domestic product of $705 billion. Economic growth since 1995 has been slightly lower but has still averaged around 8 % over the period to 1995 to 2000.

Over the period 1980 to 1995 the economy has grown at a much faster rate than the population, GDP per capita has increased over this period from $166 to $580, with the annual growth rate in GDP per capita over the period 1990 to 1995 averaging 10.7 %.

Information on the structure of GDP shows marked differences in the trends of the major sectors of the economy. The contribution of the agricultural sector to overall GDP has declined from 30 % in 1980 to 20 % in 1995, whereas the share of the service sector has increased from 21% in 1980 to 31 % in 1995 and this increasing trend is expected to continue for some time. The share of industrial output in total GDP has been more variable, but it is still by far the most significant sector accounting for nearly half of total GDP.

Table A1.1 Summary of national statistics

	1980	1990	1995	% change 1990 - 1995
Population (M)	987	1143	1211	1.2
Land area (M Sq km)	9.6	9.6	9.6	
GDP (1995 US$ billion)	164	398	702	12
Industry share (%)	49	42	49	3.1
Services share (%)	21	31	31	-0.2
Agriculture share (%)	30	27	20	-5.3
GDP per capita (1995 US$)	166	348	580	11
Urban population as % of total	24	26	29	1.9
Livestock (M heads)	787	1013	1358	6.0
Population in absolute poverty (M)	-	85	65	-5.2
Life expectancy at birth (years)	-	-	70.8	
Literacy rate (%)	-	-	88	

Within industry, Table A1.2 shows that manufacturing industry is responsible for the overwhelming share of industrial value added with 83.5% of the total in 1994. Metals, engineering, chemicals, food and drink and textiles are all significant industrial sub-sectors.

Table A1.2 Composition of value added by sector in 1994*

Sub-sector	% of value added
Manufacturing	83.5
Metals	*13.6*
Non metallic minerals	*6.4*
Chemicals	*10.7*
Engineering	*22.7*
Food and Drink	*11.7*
Textiles	*11.4*
Other	*7.0*
Fuel extraction	10.5
Utilities	6.0

* *includes only those industrial enterprises with independent accounting systems*

Society

Approximately 71 % of the population live in villages and rural areas. However, China's urban population is rapidly increasing as the country's economy grows. This is resulting in a large increase in the demand for energy for the residential and transport needs of the urban population.

At the end of the 1980s the proportion of China's population officially classified as living in absolute poverty stood at 85 million. By 1995 this had declined to 65 million and a government report published in 1997 found that the number had fallen to 58 million, representing about 4.8 % of the population.

The number of people employed is over 600 million. In 1994 over half of these (54%) were still employed in farming, forestry or fishing, with a further 16 % in manufacturing industry. The service sector accounted for just 10 % of all employees. However, these proportions are likely to change rapidly in the future, with the changing structure of the economy.

Energy resources

Coal is the most abundant primary energy resource in China, with proven reserves of around 1000 billion tonnes, meaning that China has the third largest coal deposits after the United States and the former Soviet Union. Recoverable reserves are thought to be around 115 billion tonnes of which bituminous coal accounts for 75%, anthracite for 12 % and lignite for 13 %. Of the total reserves around 83 % are classified as suitable for power generation having a sulphur content of 1.15 % and an average ash content of 17 %.

According to a 1993 study, the estimated oil reserves total 94 billion tonnes and the natural gas resource is about 38 billion m^3. However, proven reserves are lower, representing about 20 % of the total reserves for oil and just 3 % for natural gas.

Nuclear fuel resources include natural uranium and proven reserves can satisfy China's need for nuclear power development in the near future.

China is also well endowed with renewable energy resources. It has the world largest hydropower resource, with a technical potential of 380 GW or nearly 2000 TWh of electricity generation per year. At present only about 14 % of the total hydropower resource has been developed and utilised. The estimated total wind energy resource is about 250 MW, mainly distributed in two major wind belts in the north and along the coast. In 1998, the installed capacity of wind turbines was only around 200 MW. The solar resource in China is also promising, with more than two-thirds of the country's territory having an annual sunshine time of over 2,000 hours and an annual radiation of about 0.6 MJ per m^2. Annual biomass production totals around 250 million tonnes of coal equivalent, of which fuelwood accounts for 100 mtce and agricultural wastes about 150 mtce.

NATIONAL DEVELOPMENT OBJECTIVES

In 1995 the Chinese government published the Ninth Five Year Plan (1996-2000) and Outline of the Long-Term Objectives through to the year 2010 for the Economic and Social Development of China. The longer-term objectives to 2010 include doubling GDP between 2000 and 2010. In relation to energy use the plan includes the following:

- Research into the collection and utilisation of coal-bed methane, coal washing and coal beneficiation;
- Rehabilitation of low efficiency units in old power plants and information dissemination on co-generation, energy conservation in power plants and clean coal combustion techniques;
- The renewable energy sector to focus research on wind, small hydro, solar and geothermal energy.
- In the industrial sector research and information dissemination on energy conservation techniques for industrial boilers and kilns will be strengthened and other focus areas will include steel electric furnaces, steel alloy production and electrolytic aluminium production.
- In urban areas more efficient centralised heating systems and coal briquette combustion systems are to be implemented.

- In rural areas the focus is on increasing energy supply, promoting renewables, improving the efficiency of cook stoves, household lighting and household heating and to improve the energy efficiency of town and village enterprises.

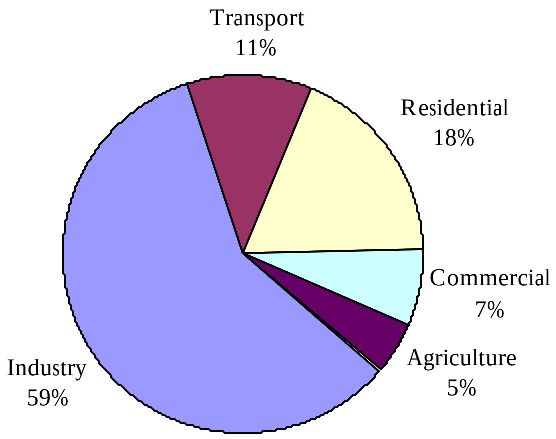
ENERGY USE AND GREENHOUSE GAS EMISSIONS

Energy use

China is currently the second largest energy consumer in the world, following the United States with an annual consumption of commercial energy in 1998 of 34,560 PJ. Coal is by far the most important energy source, accounting for 71.5 % of China's primary commercial energy use in 1998, with oil representing 24 % and gas and primary electricity (from nuclear and renewables) both having a share of between 2 % and 3 %. Non conventional fuels, such as traditional biomass, are a further important source of energy, with an estimated consumption in 1998 of 8630 PJ.

Figure A1.1 shows that the industrial sector dominates the final consumption of commercial energy, being responsible for nearly 60 % of the total 1998 energy use. Residential energy consumption comes a distant second with 18 %, although if non-commercial fuels are included then the share of residential consumption in total final energy consumption rises to 39 %.

Figure A1.1 Division of final commercial energy consumption between major sectors



China’s energy to GDP ratio has declined by more than 50 % since 1980 as economic growth outpaced increases in energy use, but in 1997 it was still 46 GJ/k$ (on an exchanged rate-based measure), nearly five times higher than the UK. Despite high levels of absolute energy use, China's per capita primary energy consumption is low, but rising. In 1980 China's energy consumption was 26 GJ per capita, but by 1998 this had grown to 32 GJ per capita. For comparison, in 1998 the UK’s per capita energy consumption was 192 GJ.

Greenhouse gas emissions

In 1990 emissions of the three most important greenhouses gases (carbon dioxide, methane and nitrous oxide) totalled 2822 million tonnes CO_2 equivalent. Carbon dioxide is by far the most important of these greenhouse gases, responsible for about 70 % of the total. The largest contributor to CO_2 emissions is fuel combustion, which accounts for 96 % of which the energy and manufacturing industries are the most significant sources.

Methane accounts for most of the other emissions of greenhouse gases, with agriculture and fuel production and extraction being important sources.

Table A1.3 1990 Greenhouse gas emissions in China (kt)

	CO_2	CH_4	N_2O
Total fuel combustion	2004107	3034	230
Energy Industries	*637712*	*62*	*230*
Manufacturing Industries and Construction	*834048*		
Transport	*113447*		
Other Sectors	*418901*		
Emissions from biomass	*641248*	*2971*	
Total fugitive emissions from fuels		8866	
Total industrial processes			
Total agriculture		16340	130
Enteric fermentation		*4525*	
Manure management		*661*	
Rice cultivation		*11155*	
Agricultural soils			
Prescribed Burning of Savannahs			
Field Burning of Agricultural Residues			*20*
Other			*110*
Total land-use change & forestry	-328533		
Total waste		899	
National total	2098095	29139	360

Trends in energy use and CO_2 emissions

Reference case projections by the US Energy Information Administration anticipate that economic growth in China will average 7.1 % over the period 2000 to 2010 so that by the end of this period GDP will exceed $2000 billion and GDP per capita will have reached $1600. Improving primary energy intensity means that the demand for energy will grow at a slower rate, but it is still projected to increase by 4.5 % per year to reach over 70000 PJ by 2010. This is expected to have a knock-on effect on CO_2 emissions, which are forecast to increase to 5100 million tonnes in 2010.

CHINESE ATTITUDES TOWARDS THE CDM

The Chinese government supports the purpose of the CDM to assist developing country parties in achieving sustainable development and to assist developed countries in achieving compliance with their quantified emission limitation and reduction commitments. Its views on some of the key issues are that:

- it must be ensured that CDM project activities are supplemental to domestic action by developed countries;

- whether a project promotes sustainable development should be decided by the host country and not by other Parties or international institutions.
- a minimum number of CDM projects should be implemented in the least developed countries to meet their special needs.
- CDM projects should be implemented between Annex I and non-Annex I country parties and the governments of the participating Parties should bear overall responsibility for the CDM project and be responsible for the private or public entities that may be involved.
- CDM activities should be project based and project by project baselines should be applied, rather than country baselines.
- Funding for such projects should be additional to ODA, GEF and other financial commitments of the developed countries and technology transfer under the CDM should be additional to the Parties' commitments on technology transfer under the UNFCCC.
- the concept of fungibility between mechanisms is total unacceptable.

OPPORTUNITIES FOR CO_2 MITIGATION

The following sections provide an overview of the main energy using sectors of the Chinese economy and identify a range of CO_2 abatement options for CDM screening.

Power sector

China has an installed power generation capacity of about 250 GW, the second largest in the world. In 1997 it produced 1150 TWh of electricity, of which 74% was from coal, 17 % from hydroelectricity, oil 7%, nuclear 1% and other sources 1% (gas and renewables). Power shortages were once a serious impediment to economic development, but as a result of rapid capacity build-up during 1997 and 1998 the system now suffers from over capacity. Much of the investment has been in new, large plant with relatively good efficiency levels and which are operated with a reasonably high capacity factor (above 50% utilisation). The proportion of electricity generating capacity provided by high temperature high-pressure units increased from 56% to 84% between 1974 and 1993. However, there are still a large number of smaller plant which operate on low loads (as low as 10%) which are only used for a few weeks a year. With the exception of large hydropower, renewable sources of energy make only a very small contribution to electricity generation.

Despite the recent investment, it is expected that around 190 GW of new electricity generating capacity will be required over the period 2000 to 2010. Official Chinese projections suggest that thermal power plants are likely to account for around 75% of this new capacity, although some expansion of oil and gas-fired capacity is likely around the coastal areas which are experiencing booming economic development.

China has been successfully extending electricity grids into most rural areas, with 92% of villages and 87% of rural households now having access. The remainder tends to be in particularly remote areas, where local resources are not adequate to generate their own electricity and this makes electrification unlikely in the short term.

Self-generation of electricity in combined heat and power units accounts for about 12% of capacity (15 GW) and 8% of total generation (60 TWh). Medium and large scale units (>25 MW) are typically found in refineries and large chemicals and food plants. They are often combined with district heating systems when located in the heating zone. There is considerable potential for further CHP capacity in the steel, chemicals, paper, rubber, textiles, printing and dyeing, and food industries. It has been estimated that the capacity of CHP plant in these sectors will double between 1988 and 2000.

CO_2 mitigation opportunities

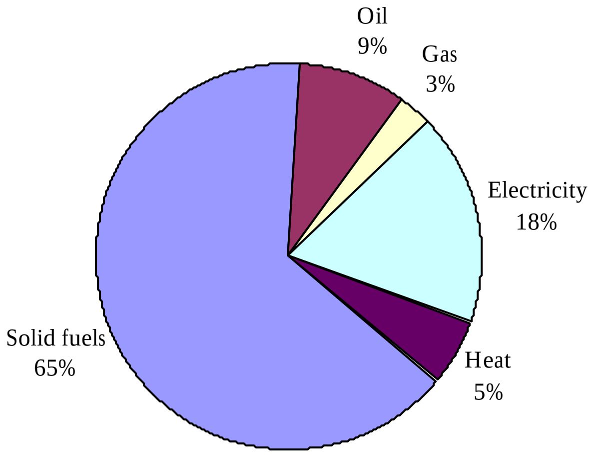
Greenhouse gas mitigation opportunities in the short-term will involve increasing the efficiency with which coal is used in existing power stations. The projected expansion of the power sector means that, in the medium to longer term, there are also opportunities for the construction of electricity generating plant that are less carbon intensive, such as clean coal, gas and renewables.

Renovating existing plant	The current energy efficiency of coal plants is around 30 % and in the short term large reductions in CO_2 emissions could be achieved by adopting energy conservation measures in power stations, renovating or replacing middle and low pressure coal units and increasing the proportion of high pressure, larger scale generating units (>300 MW).
Clean coal plant	The introduction of advanced coal technologies such as PFBC and IGCC will be important in reducing CO_2 emissions in the longer term. However, in the period it up to 2010 these technologies are unlikely to have a large role in reducing CO_2 emissions.
CCGT	In the longer term, natural gas could meet up to one-third of future power generation needs by utilising low-cost natural gas sources. In the period up to 2010, the deployment of combined cycle gas turbines will be most important in the coastal regions in order to satisfy the fast growing peak load.
Nuclear	There is likely to be opportunities for additional nuclear power plant, particularly in the eastern coastal region that has a shortage of other energy resources.
Large hydro	There is a large potential, of which only a small fraction is currently utilised, although there are concerns over the environmental and social impacts of large hydro (see later).
Small hydro	Small-scale hydro is a widely distributed resource and particularly concentrated in the relatively remote south-west of the country. There are currently more than 45,000 small scale hydro stations in operation, with an installed capacity of 19 GW. However, the total exploitable resource is around 72 GW.
Wind	China has a wind resource suitable for commercial exploitation and aims to have around 1000 MW of wind capacity installed by 2010. The most promising sites are those in the south-east coastal areas and in the north-western provinces of Inner Mongolia and Xinjiang. Wind power may also be valuable for supplying electricity to island communities that have no grid connections.
Biomass	Electricity generation from biomass may be particularly attractive in the south of the country. The government is currently setting up a demonstration project in Liu Zhou.
PV	The total PV resource deployed is estimated to be around 8 MW, although the government are interested in increasing this total by using PV for rural electrification in western China.

Industry sector

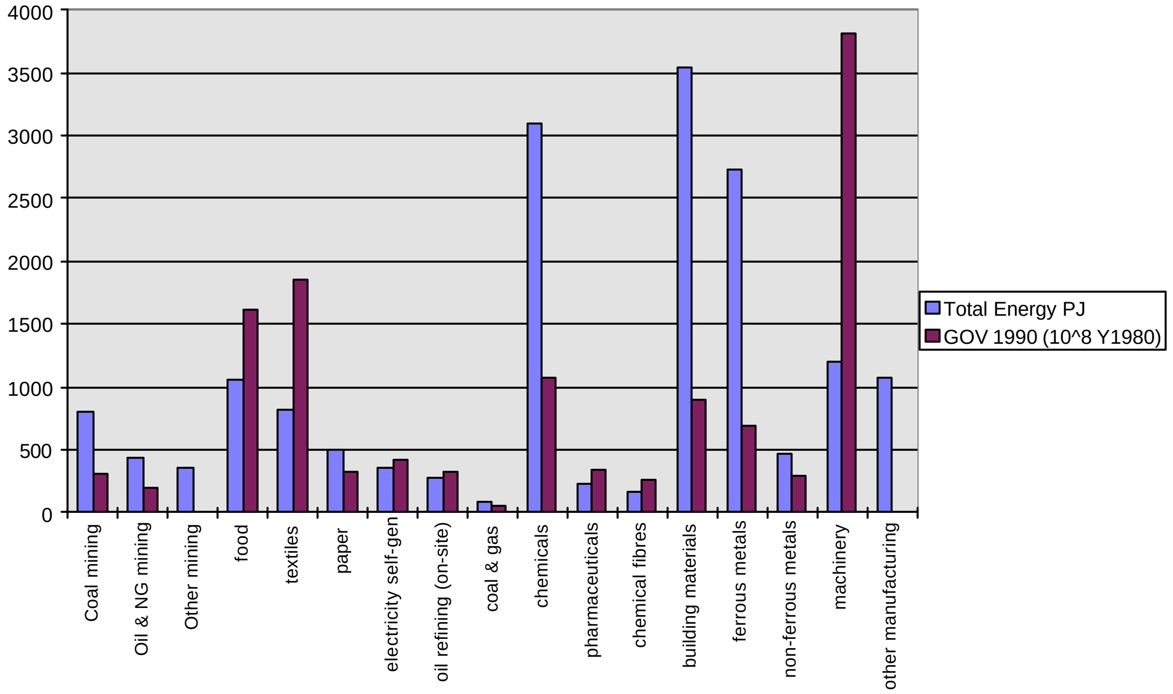
Fuel consumption in the industrial sector is dominated by solid fuel (coal), with electricity also playing a significant role as shown in Figure 4.2. Since electricity generation is also dominated by coal, this fuel underpins industrial energy consumption to a very large extent.

Figure A1.2 Fuel split for the industrial sector



The split of energy consumption between sectors is shown in Figure A1.3. Also shown in this graph is the output value for each sector.

Figure A1.3 Energy consumption and gross output value by industrial sector



Two points can be noted from this graph:

- The largest energy users (building materials 23%, chemicals 20% and ferrous metals 18%) are responsible for a relatively small proportion of the gross output value (6%, 7% and 5%

respectively). These are energy intensive industries producing relatively low value basic products.

- The largest sectors in terms of gross output value (machinery 32%, textiles 16% and food 13%) are not energy intensive, accounting for a small proportion of the overall industrial energy consumption (8%, 5% and 7% respectively).

This has important implications when considering opportunities for investment in industrial plant, since purely concentrating on energy consumption as a guide to the 'size' of a sector can be misleading.

Building Materials Industry

This sector covers the manufacture of cement, concrete products, flat glass, fibreglass, bricks and tiles. China is one of the largest producers of these products in the world, due largely to very rapid growth rates (typically these sectors increased physical output by 3-4 times between 1980 and 1992). The scale of production in many plants tends to be small by international standards. The way the industry has grown has tended to be via thousands of village-operated, rural plant. Whilst this provided an easy solution for meeting local demand and dealing with transportation difficulties, it has lead to a large capacity of outdated technology. In many cases, there is substantial over-capacity, with plant only being operated when there is a sudden local demand (e.g. at the onset of a new building project etc.). The small scale and intermittent nature of production, combined with outdated technology lead to low efficiencies. Specific energy consumption (SEC) figures for major products are shown in Table 1.4 below, and are compared with typical figures for the UK.

Table A1.4 Specific energy consumption: comparisons with UK

	China - typical SEC GJ/tonne	UK - typical SEC GJ/tonne
Cement – dry process	5.3	3.9
Cement – wet process	6.6	5.0
Cement – vertical kilns	5.3	-
Flat glass – average	25.0	10.3
Bricks – key enterprises	3.5	3.3
Bricks – rural enterprises	4.8	-
Bricks – vertical kilns	9.7	-

Over the 1980s and early 1990s, the sector grew rapidly. Future growth in these sectors, as market forces increasingly influence the economy, is more uncertain, and will depend on the region. In many areas there is significant over-capacity, and several smaller plant are being squeezed out of the market by more commercially viable larger plant. However, in some regions where there is strong economic growth and therefore a greater level of construction activity the markets for these products may remain strong.

Other Sectors

The chemicals industry energy consumption is dominated by fertiliser, basic inorganics and basic organics (together accounting for 90% of the sector's energy demand), and China is the world's largest producer of ammonia. The processes used are often different from those in other countries as a result of the dependence on coal. For example, ammonia is generally produced via gasified coal rather than using natural gas or naphtha. Future growth in the sector is likely to be concentrated on some of the higher product value areas such as pharmaceuticals (which is expected to grow at around 3% per year).

China is amongst the three largest producers of crude steel in the world (81 Million tonnes in 1992). There has been a systematic programme of investment by the government to improve the efficiency of plant, through conversion of open-hearth furnaces to basic oxygen furnaces, introduction of continuous casting in some plant, and a large number of improvements to ancillary plant. Nevertheless, it is estimated that major processes are still less efficient than plants in developed countries and efficiency lags are shown in Table A1.5 below.

Table A1.5 Efficiency lags of Chinese steel plant compared to international standards[3]

	Efficiency Lag
Coking, ironmaking, open-hearth processes	5-15%
Converters and electrical furnaces	30-40%
Primary rolling	15%
Hot rolling	30%

Food manufacturing and textiles also have a significant energy consumption in China with approximately 1,100 PJ used in food manufacturing and 800 PJ in textiles. These two sectors also have the highest added value contribution to the economy next to the machinery (engineering) sector. Processes in the food industry tend to be primitive and are mainly associated with processing staple products whereas, in textiles, the processes are more developed and processing mills are similar to those found in other, more developed, textile manufacturing countries.

Greenhouse gas mitigation opportunities

Building Materials

As described above, the structure of the building materials industry is substantially different from that in the UK. Production tends to be distributed amongst thousands of small rural plant using different technologies with different abatement options than would be relevant to UK industry.

The technologies are identified below.

Cement - small plant

Renovation projects include mechanisation of vertical kilns that increases capacity and improves efficiency as well as improving environmental performance;.

Retrofit improvements to the raw material grinding stage include automating the load control, installing high-efficiency classifiers, installing roller grinders and installing improved motors.

Improving the control of raw material ingredients and control of the pre-mixing stage

Improving the fabric of vertical kilns; optimising kiln size and shape and using high-quality refractory lining and insulation materials.

Computerised kiln operation to optimise air, fuel, raw materials and temperature control.

Installing roller grinders to the clinker-grinding stage

Cement Wet-process

Wet to dry cement process conversion. The wet cement process takes raw materials and mixes them in a wet slurry prior to insertion into the kiln. A long kiln is usually required to give enough time for the mixture to dry out thermally, and this absorbs a large amount of energy. A more efficient technique is to mix the raw materials dry. This requires more mixing (electrical) energy, but this is more than made up for by savings in thermal (fossil fuel) energy. The conversion usually requires a total kiln re-fit, and would be undertaken at the end of the lifetime of the wet-process plant. Intermediate steps include conversion to semi-dry or semi-wet processes where a certain amount of mechanical de-watering is carried out to reduce the thermal drying energy requirements. Again, this requires major plant re-fitting and would usually be considered as part of plant replacement cycles.

Retrofits include installation of heat-resistant steel chains to improve heat transfer, high quality refractory lining and improved insulation, improved burners, improving coal-pulverising plant and using more mineral additives.

Flat Glass

The manufacture of glass requires very high temperatures to be maintained for long duration to achieve good quality melt, and quality of refractories and insulation on the furnace walls and roof are very important. The better the quality of the refractories, the more insulation can be used reducing heat loss.

Reducing furnace residence time required to refine the glass can be achieved through better firing techniques boost heating, and bubblers to improve glass convection flow.

Waste heat can be recovered for a variety of uses including raw material pre-heating or generating electricity.

Control systems for optimising the air:fuel ratio, raw material feed, temperature control etc. can lead to significant energy savings.

High efficiency motors (e.g. for combustion air fans).

Bricks

Economies of scale. One of the main efficiency improvements is to encourage larger plant with a higher load factor

Using hollow bricks can reduce firing energy requirements because of their lower mass and improved heat transfer (also improve insulation in the building), but there have been some technical problems introducing to China because they were produced with poor physical strength.

Use of additives to the bricks such as fly-ash can reduce energy consumption of brick firing.

Metals

Iron and Steel

Top-gas turbines. Electricity can be generated from blast furnaces by utilising the high-pressure off-gases from the furnace in a turbine. This technique tends to only be relevant for larger blast furnaces where the pressures are sufficiently high.

The off-gases from blast furnaces have a reasonably high calorific value due to CO content, and this can be used in boilers for steam or electricity generation. Increasing the collection of blast furnace gas can often be a cost-effective option as long as there is a use for it on-site or nearby.

Blast furnaces are traditionally fired with coke, but the manufacture of coke is itself a fairly energy intensive and polluting process. Injection of coal directly into the blast furnace to reduce the coke requirement is a technique that is becoming widespread throughout the world, and is being installed in China.

Continuous casting represents one of the largest single measures for saving energy. It replaces a heating and rolling stage by casting directly into slabs and billets. The conversion to continuous casting tends to be done for many reasons (including increased production capacity and quality) other than just energy.

There is a high potential for efficiency improvements for a wide range of equipment including boilers, furnaces, electric motors and rolling plant.

Primary Aluminium Reduction of voltage losses through improved transformers and reduced electrical densities of transmission lines. Also optimising the design of the electrolyser (size and shape) to enhance conductivity.

Improving the make-up of the electrolyte can enhance the energy efficiency of the process.

Other Industry Sectors

Chemicals Renovation options for ammonia plant include improving decarbonising systems and recovery of fuel gases and emitted hydrogen, recovery of waste heat, improving heat-transfer efficiency, introducing closed-cycle technologies for heating and cooling water. One renovation project at a small plant in Shandong Province managed to recover enough waste heat to obviate the need for primary steam generation.

Textiles There are a range of highly cost effective technologies for improving the efficiency of textile mills. These are largely associated with textile finishing and include measures such as improved drying techniques, fabric finishing (stentering) control and pre-drying techniques, and improvements process and product scheduling and dyeing techniques.

Lime The lime industry is less organised and more spread out than the cement industry, and so energy efficiency programmes are more difficult. The main opportunities for efficiency improvements will therefore be through relatively simple measures such as better management of plant and introduction of control systems to improve the size-mix of limestone, the coal/limestone ratio, air flow, temperature distribution etc.

Residential

The pattern of residential energy demand in both urban rural areas is changing rapidly in China. Increasing per capita incomes are allowing larger living areas in Chinese households and generating an increasing demand for household appliances. Consequently, the demand for high quality energy from electricity and gas is increasing, whereas the consumption of coal and non-commercial fuels, such as biomass is decreasing gradually. Over the period 1980 to 1998 electricity demand increased over ten-fold and gas use increased by more than three times. Nevertheless, in 1998 coal and non-conventional fuels still accounted for 90 % of total energy use (down from 98 % in 1980).

Mitigation options

Increasing demand for high quality commercial fuels and increasing use of electricity in Chinese homes will tend to increase CO_2 emissions. Many opportunities exist to ensure that the most efficient technologies are used to provide these new domestic energy services.

Lighting — Compact fluorescent lamps use around one-third to one-quarter of the energy of a standard incandescent light bulb and can be used as a direct replacement in most situations. China is one of the major manufacturers of these lamps with a production of 80 million units in 1995, of which around 60 % are exported.

Electrical appliances — Appliance demand is growing rapidly and the introduction of energy efficient appliances can help to reduce the consequent increase in electricity. Fridges are among the most common household appliances in China and by using energy efficient models around 160 kWh per year per fridge can be saved compared to a standard model.

Biogas digesters for cooking — Biogas digesters can be used to turn kitchen and rural wastes into biogas. Small household biogas digesters of 6 m^3 have been developed that can generate around 1.8 m^3 of biogas per day. As well as displacing coal use in cooking, these digesters can help reduce methane emissions.

Fuel switching to town gas — Increasing the proportion of the population who have access to town gas (natural gas, LPG or coal/oil gas) will enable the share of residential energy demand met by coal to be reduced substantially.

Water heating — Increasing the number of solar water heaters can reduce coal and biomass consumption for heating water. This technology is particularly attractive in northern and north-eastern China.

Thermally efficient homes — Thermally efficient homes are attractive where space heating is required. Passive solar designs with natural circulation are low cost and have easy operation and maintenance and so are particularly suited to rural areas. In northern China such houses can reduce energy use by 0.6 GJ per m3.

Commercial and service sector

The commercial and service sector consists of shops, restaurants, offices and other for-profit businesses, plus academic and educational buildings. Traditionally buildings in this sector have been low rise and shared similar characteristics with residential houses. Most of them are not insulated and around half need extensive winter space heating. However, over the last 20 years there has been a rapid increase in the construction of fully air-conditioned commercial buildings and construction

Energy use in the commercial sector was about 1500 PJ in 1998, representing only 7 % of total final energy consumption. Coal and oil predominate as energy sources and between them account for around 80 % of total fuel use, with electricity making up most of the remainder. Energy is mainly used for space heating and lighting, with cooking also important given the popularity of restaurants and worker cafeterias in China.

Mitigation opportunities

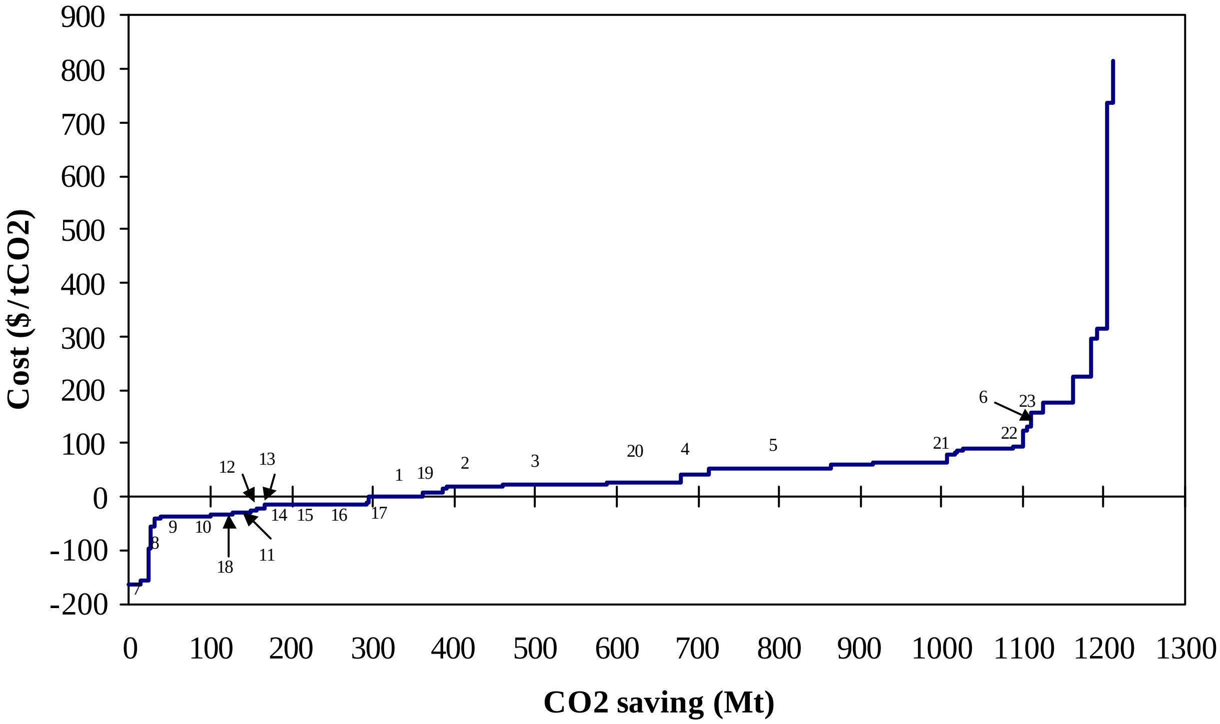
Many of the mitigation options that have been identified for the domestic sector in China are also applicable to the service sector. In addition, some of the more modern buildings could benefit from the additional measures shown below.

Efficient lighting	Lighting retrofits in commercial buildings include the replacement of standard fluorescent tubes with more efficient lighting and introducing lighting controls, such as occupancy sensors.
Heating, ventilation & air conditioning	Only the more sophisticated modern buildings have HVAC controls. Typical buildings in the commercial sector lack even rudimentary automatic-control devices.

TECHNO-ECONOMIC SCREENING

Data on the cost and performance of the mitigation options identified in the previous section have been used to generate a cost-abatement curve for CO_2 emissions and this is shown in Figure A1.4. This shows the scale of CO_2 emissions savings that could be possible over the period to 2010 compared to business-as-usual. In all, CO_2 emissions savings totalling more than 1200 Mt have been identified, of which nearly 300 Mt are calculated to be cost-effective. This compares to CO_2 emissions in 1990 of 2100 Mt and projected CO_2 emissions in 2010 under business as usual of 5100 Mt.

Figure A1.4 CO_2 cost-abatement curve for China



Many of the larger cost effective opportunities are in manufacturing industry, with significant savings in steel, non-metallic minerals, chemicals and cement. Replacing conventional bulbs in the domestic sector with compact fluorescent lights would also provide a significant cost effective saving.

The power sector also contains many large opportunities for reducing emissions, through the introduction of coal washing, the use of gas in combined cycle turbines and increased use of hydro and nuclear for electricity generation. However, all these options have small positive net costs.

Other, more expensive options include further energy efficiency options in manufacturing industry, introducing cleaner fuels to the domestic sector and power generation from wind, biomass and clean coal technology.

Table A1.6 Summary of the CO_2 savings and cost of abatement for China

Key	Option	CO_2 saving $MtCO_2$	Typical cost of abatement ($/tCO2)
	Power		
1	Coal washing	58.17	1
2	CCGT	67.94	17
3	Large hydro	113.79	22
4	Small hydro	34.14	42
5	Nuclear	150.5	51
6	Biomass	3.79	132
	Industry		
7	Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	13.83	-150 to -200
8	Improvements to aluminium smelting	10.46	-95 to -100
9	General steel process improvements	55.34	-35 to -40
10	Low cost options in engineering	5.51	-33
11	Continuous casting of steel	21.71	-29
12	Ammonia plant renovation	34.77	-15 to -24
13	Low cost improvements in glass	7.47	-19 to -22
14	Hollow bricks (non-metallic minerals)	59.54	-14
15	Low cost improvements in chemicals	19.23	-13
16	Small scale cement plant renovation	19.24	-11 to -13
17	Low cost options in other industries	10.35	0 to14
	Domestic and Commercial		
18	Lighting improvements	24.91	-32 to -54
19	Biogas	22.95	8
20	Town gas	92.56	26
21	Thermally efficient homes	2.67	84
22	Solar water heaters	4.45	123
23	Efficient fridge	6.39	157

ENVIRONMENTAL, SOCIAL AND DEVELOPMENT SCREENING

Following the economic analysis, a large number of the options in each sector that may be suitable for CDM funding have been subjected to further screening on environmental, social and development grounds.

Power Sector

In the power sector, the environmental, social and development impacts of the various greenhouse gas mitigation options have been assessed in relation to the building of new coal pulverised power plants. The following table summarises the findings.

Coal washing	Coal washing will improve the generation efficiency of coal power stations so reducing emissions of non-greenhouse gas pollutants, helping to improve local air quality. It also reduces the quantity of ash which results from combustion which, being highly leachable, can adversely effect water quality.
CCGT	Compared to coal-fired power stations, CCGTs produce almost no sulphur oxides and particulates. Ash disposal is also not a problem. The fast build times associated with CCGT, will enable the rapidly increasing demand for electricity in the coastal regions allowing the economy to expand, helping to create employment.
Large hydro	Large hydro plant will reduce non-greenhouse gas emissions and can incorporate flood protection measures. However, as they involve flooding large areas of land, they can have a negative impact on local communities (especially farmers) and on wildlife.
Small hydro	Small hydro is a clean source of electricity generation and so can help improve local air quality compared to fossil alternatives. In rural areas the provision of electricity can improve irrigation, so stimulating rural development and helping to reduce poverty.
Nuclear	Nuclear power plants do not burn fossil fuels and therefore will have a positive impact on air quality. However, safe disposal of radioactive waste is likely to remain a serious problem.
Biomass	The generation of electricity from biomass will reduce emissions of sulphur dioxide that are associated with coal-fired power generation, helping to reduce the problem of acid rain in China. The planting and harvesting of biomass could provide additional employment to local communities, as it is relatively labour intensive. This provision of jobs could help with rural development and help to reduce poverty

Table A1.7 Summary of sustainability impacts of potential CDM options in the power sector

	Coal washing	CCGT	Large hydro	Small hydro	Nuclear	Biomass
Environmental impacts						
Air quality	+	+	+	+	+	+
Water quality	+	+	0	+	+	0
Flood prevention	0	0	+	0	0	0
Soil conservation	0	0	-	0	0	+
Solid waste	+	+	+	+	-	0
Noise	0	0	0	+	0	0
Biodiversity protection	0	0	-	0	0	+
Social and development benefits						
Employment	0	+	0	+	0	+
Rural development	0	0	-	+	0	+
Poverty reduction	0	0	0	+	0	+
Benefits to key groups	0	0	-	0	0	0

Industry

The following tables summarise the social and development benefits of key mitigation options in manufacturing industry:

Hollow bricks Low density brick manufacture, which is normally achieved using perforated or 'frogged' bricks, not only reduces energy consumption per brick, and hence emissions, but also conserves clay materials allowing a brick to be made with less material. This not only conserves land, but also reduces the emissions associated with firing of clay products. In addition to conserving soil, waste is reduced from clay screening and, because of efficiency improvements, there are benefits for employment and rural development.

Chemical plant improvements Chemical plant improvements (particularly distributed ammonia plant renovation and other low cost improvements in chemicals) mainly affect air quality, both local and CO2, and because of efficiency improvements can have a positive impact on employment and general rural development. In the case of ammonia plants, the potential for lower cost fertilisers has a potential impact on poverty reduction in agricultural communities.

Continuous steel casting Continuous steel casting offers energy saving improvements and therefore GHG emissions and local air quality improvements. However, because it is also a mechanised process it will have a negative effect on employment. Continuous casting tends to be operated in larger steel plants and could result in the loss of smaller scale plants with adverse consequences for rural development.

Improvements to aluminium Primary aluminium smelting uses high levels of electricity and is concentrated in larger smelting plants. Improvements in the smelting process will have a *smelting* significant impact on air quality because of lower electricity use, and local emissions improvements, will benefit employment through general economic development, but is likely to have a negative impact on rural development as plants become more concentrated into larger units.

Improved cement plants Cement plants are identified particularly as benefiting from plant improvements, not only through air quality and reduced energy (global emissions) improvements, but also because of water quality and solid waste improvements. Updating cement plants and improving dust and effluent handling, at relatively little expense, can have a significant effect on levels of waste for removal and dumping and on water course pollution. In addition, small-scale regional cement plants can benefit from low cost investment which offer benefits for employment and rural development.

Improvements in other sectors Other low cost improvements in areas such as textiles, plastics, wood, cement, glass and ceramics benefit air quality and potentially offer employment and rural development benefits. Clearly there is a conflict between the drive towards increasing the size of manufacturing plants, with associated efficiency benefits, and the negative effects this will have on more scattered rural development and poverty reduction. Small-scale low cost investment tends to favour rural and small scale enterprise activities.

Table A1.8 Summary of sustainability impacts of potential CDM options in manufacturing industry – (1)

	Low density bricks	Ammonia plant renovation	Low cost improvements in chemicals	Continuous casting of steel	Miscellaneous low cost steel improvements
Environmental impacts					
Air quality	+	+	+	+	+
Water quality	0	0	0	0	0
Flood prevention	0	0	0	0	0
Soil conservation	+	0	0	0	0
Solid waste	+	0	0	0	0
Noise	0	0	0	0	0
Biodiversity protection	0	0	0	0	0
Social and development benefits					
Employment	+	+	+	-	+
Rural development	+	+	+	0	+
Poverty reduction	0	+	0	0	0
Benefits to key groups	0	0	0	0	0

Table A1.9 Summary of sustainability impacts of potential CDM options in manufacturing industry – (2)

	Small scale cement plant improvements	Low cost improvements in textiles, plastics and wood	Aluminium primary smelting improvements	Low cost measures on cement and glass plants
Environmental impacts				
Air quality	+	+	+	+
Water quality	+	0	0	0
Flood prevention	0	0	0	0
Soil conservation	0	0	0	0
Solid waste	+	0	0	0
Noise	0	0	0	0
Biodiversity protection	0	0	0	0
Social and development benefits				
Employment	+	+	+	+
Rural development	+	+	-	+
Poverty reduction	0	0	0	0
Benefits to key groups	0	0	0	0

Residential and commercial sectors

The main environmental, social and development impacts of mitigation opportunities in these sectors are summarised below.

Lighting improvements — Lighting improvements such as the use of CFLs and better lighting control can save electricity and so also reduce non-greenhouse gas emissions associated with electricity generation.

Biogas digesters — Biogas digesters can help reduce methane emissions by burning the gas produced. In rural areas they provide inhabitants with a clean source of fuel for cooking, thus reducing the health impacts associated with emissions from cooking on coal or wood stoves.

Town gas — The introduction of a gas network in urban areas can provide a cleaner fuel source than coal for cooking and so substantially improve local air quality and eliminate the need for ash disposal.

Thermally efficient homes — Thermally efficient houses will reduce the need for heating fuels and therefore reduce the associated non-greenhouse gas pollutants. There may also be a net positive effect on expenditure by low-income households, helping to reduce poverty. The construction of such homes should provide additional local labour for the incremental building requirements over a standard house.

Solar water heaters — Solar water heaters enable both rural and urban households to move away from coal and wood for water heating, thus reducing local air pollution and eliminating the need for ash disposal. As these heaters are manufactured in China they can help create additional employment.

Efficient fridges Efficient fridges use less electricity than normal fridges and so help reduce emissions of non-greenhouse gas from power generation. Since the life-cycle costs of these appliances can be less than a conventional fridge, they can reduce energy expenditure and so help poorer families own a fridge thus helping to improve their quality of life.

Table A1.10 Summary of sustainability impacts of potential CDM options in the residential sector

	Lighting improvements	Biogas digesters	Town gas	Solar water heaters	Thermally efficient housing	Efficient fridges
Environmental impacts						
Air quality	+	+	+	+	+	+
Water quality	0	+	0	0	0	0
Flood prevention	0	0	0	0	0	0
Soil conservation	0	0	0	0	0	0
Solid waste	0	+	+	+	+	0
Noise	0	0	0	0	0	0
Biodiversity protection	0	0	0	0	0	0
Social and development benefits						
Employment	0	+	0	+	+	0
Rural development	0	0	0	0	+	0
Poverty reduction	+	+	0	+	+	+
Benefits to key groups	0	+	0	0	0	0

PRIORITISATION OF KEY CDM OPPORTUNITIES IN CHINA

The following table summarises the key CDM opportunities in China, scoring them on the cost of mitigation, their potential for reducing emissions and their contribution to sustainable development in terms of other environmental and social and development benefits.

Table A1.11 Summary of possible CDM opportunities identified in China

Opportunity	Mitigation cost	Greenhouse gas reduction potential	Other environmental benefits	Social and development benefits
Power				
Coal washing	**	***	**	*
CCGT	**	***	**	**
Large hydro	*	***	*	*
Small hydro	*	**	***	***
Nuclear	*	***	*	*
Biomass	*	*	**	***
Industry				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	***	**	*	**
Improved aluminium smelting	***	**	*	*
General steel process improvements	***	***	*	**
Continuous casting of steel	***	**	*	*
Ammonia plant renovation	***	**	*	***
Low cost improvements in glass	***	*	*	**
Hollow bricks	***	***	**	**
Low cost improvements in chemicals	***	**	*	**
Small scale cement plant renovation	***	**	**	**
Domestic and Commercial				
Lighting improvements	***	**	*	*
Biogas	**	**	***	***
Town gas	*	***	*	*
Thermally efficient homes	*	*	*	***
Solar water heaters	*	*	*	**
Efficient fridge	*	*	*	*

From this table the following conclusions are drawn:

- Manufacturing industry offers the greatest scope for low cost CO_2 abatement, with many of the options generating substantial emissions savings. The sustainability benefits of abatement in manufacturing vary widely, but with careful selection it is possible to achieve cost effective greenhouse gas reduction while reducing other environmental burdens and promoting social and development objectives. Opportunities that can achieve these aims include low-density brick making, process improvements in steel-making, small-scale cement plant renovation and various low cost measures in low intensity sectors, such as textiles and engineering.

- Large emissions savings are also possible in the power sector, although the costs of these options are higher than in industry. Renewable energy from small hydro and biomass, in particular, brings with it many sustainability benefits, although the costs of achieving CO_2 reduction through these technologies is higher than using conventional technologies such as combined cycle gas turbines.
- In the domestic and commercial sectors, the potential for CO_2 savings is generally smaller and the options more expensive. However, the use of compact fluorescent lightbulbs to replace conventional incandescent lighting is highly cost effective, although the social and development impacts are likely to be small. More expensive as a CO_2 mitigation option is the introduction of biogas digesters, but these have the advantages of reducing both carbon dioxide and methane and bringing social and development benefits by providing a cheap source of clean fuel for cooking.
- Many of these options, including the use of renewables, improvements in the steel industry and the provision of improved lighting and cooking services in the domestic sector, are in line with national development needs identified by the Chinese government in the Ninth Five Year Plan and the Outline of the Long-Term Objectives.

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Appendix 2
India case study

India Case Study

INTRODUCTION

This case study describes the work undertaken to identify and prioritise greenhouse gas mitigation opportunities in India that might be suitable for funding under the Clean Development Mechanism. It is divided into the following sections:

- Country profile
- National development objectives
- Energy and greenhouse gas emissions
- Indian attitudes towards the CDM
- Opportunities for CO_2 mitigation
- Techno-economic screening of mitigation options
- Environmental, social and development screening of mitigation options
- Prioritisation of potential CDM opportunities

COUNTRY PROFILE

Population

India is the second most populous country in the world and in 1999 the population passed one billion people for the first time. Population growth is currently averaging around 2.1 % and it is expected that India will have a population of around 1400 million by 2025.

Economy

Economic reforms initiated in 1991 resulted in the annual growth rate during the Eighth Five Year Plan (1992-1997) averaging 6.8 %. Since 1997, there has been a slight drop in GDP growth due to slower progress in the industrial and agricultural sectors. In 1995 the gross national product of India was estimated to be $343 billion.

Despite a growth rate of 3.4 % per annum over the period 1980 to 1995, GNP per capita at $369 is still low when compared to other countries and the overall growth in the economy has had much less effect on per capita incomes due to a rapidly increasing population.

The structure of the economy is undergoing substantial changes, with the share of agriculture falling from 39.6 % to 27.9 % over the period 1980 to 1997. Over the same period the share of industrial output grew from 24.4 % to 29.3 % and that of the service sector increased from 36 % to 42.8 %.

Society

The share of the population classified as urban has been steadily increasing from 23% of the total in 1980 to 27 % in 1995, an annual increase of 3.1 %. In 1995, 48 % of the adult population was illiterate and the proportion of the population earning below the poverty level (defined as less than $1 per day at purchasing power parity) was 52.5 %, higher than the average of 32 % for all developing countries. Life expectancy has increased from 59 years in 1990 to 62 years in 1995.

Table A2.1 Summary of national statistics

	1980	1990	1995	% change 1990 - 1995
Population (M)	683.3	839.0	929.4	1.9
Land area (M Sq km)	328.7	328.7	328.7	
GDP (1995 US$ billion)	153	265.5	342.9	5.3
Industry share (%)	25.9	29.3	29.0	
Services share (%)	36.0	39.1	41.0	
Agriculture share (%)	38.1	31.0	30.0	
GDP per capita (1990 US$)	224	314	369	
Urban population as % of total	23.3	25.7	27	1.0
Livestock (M heads)	369.5	387.2	-	
Population in absolute poverty (M)	271	238	168	
Life expectancy at birth (years)		59	62	
Literacy rate (%)	41.4	52.2	52	

Energy resources

India is relatively well endowed with both renewable and exhaustible energy resources. Coal is the major exhaustible resource in the country with proven reserves of 70 billion tonnes (around 7 % of the world total), giving a reserve to production ratio of 245 years. In addition, lignite reserves have been estimated at around 28000 million tonnes.

Oil and natural gas are also important energy resources, with recoverable reserves estimated at around 750 million tonnes and 700 billion cubic metres respectively. Reserve-to-production ratios are considerable smaller than for coal, with oil estimated at about 21 years and natural gas at 38 years. India also has assured uranium resources of 34000 tonnes, of which about half are thought to be economically exploitable.

India has substantial renewable energy sources and the total potential for these has been estimated by the Ministry for Non-Conventional Energy Sources and is summarised below.

Table A2.2 Potential for renewable sources of energy in India

Renewable energy source	Potential
Biogas power	17000 MW
Solar energy	20 MW/km^2
Wind energy	20000 MW
Small Hydro	10000 MW
Large Hydro	84000 MW
Ocean energy	50000 MW

National development objectives

Planning in India takes the form of five-year plans formulated by the Planning Commission. The current plan is the Ninth Five-Year Plan covering the period 1997 to 2002. The objectives of the plan include:

- Giving priority to agriculture and rural development
- Accelerating the rate of growth of the economy with stable prices, safe drinking water, availability of primary health care, etc;
- Containing the growth rate of population;
- Ensuring environmental sustainability of the development process;
- Empowering women and socially disadvantaged groups;
- Promoting and developing people's participatory institutions; and
- Strengthening efforts to promote self-reliance.

In relation to energy use, the aim is to use resources efficiently to promote long-term sustainability and counteract the projected supply-demand gap in 2001/02. Some of the measures intended to achieve this are:

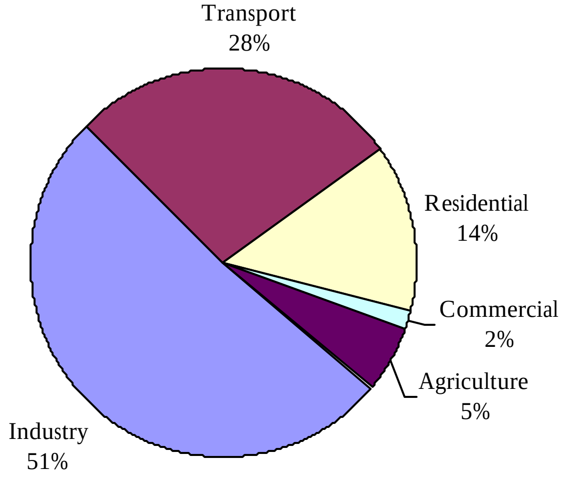
- Increased production of coal and lignite;
- Removal of subsidies so that coal prices reflect the true cost of production;
- Use improved coal utilisation technologies;
- Fuel switching from coal to oil and natural gas;
- Promotion of renewable energy resources;
- Privatisation of the power sector and the reform of electricity pricing;
- Upgrade the transport infrastructure and encourage modal shifts.

ENERGY USE AND GREENHOUSE GAS EMISSIONS

Energy use

Commercial primary energy use in India in 1998 reached 11959 PJ, with coal accounting for 54%, oil for 35 %, gas for 6 % and primary electricity (nuclear and renewables) for the remaining 4 %. Traditional fuels (such as wood, dung etc.) have been estimated to provide an additional 7900 PJ of energy. Of the commercial fuels, the biggest share of final consumption is in industry representing, 51 % of the total as shown in Figure A2.1, followed by transport with 28 %. If traditional fuels are included then it is estimated that the share of total energy use accounted for by the residential sector increases to 55 %.

Figure A2.1 Composition of final energy consumption in India by major sector



Unlike many other developing countries, India's energy intensity (as measured by the ratio of primary energy consumption to gross domestic product on an exchange rate basis) has been increasing in recent years from 23 GJ/k$ in 1980 to 27 GJ/k$ in 1997. It now has an energy intensity more than three times that of the UK. Per capita energy consumption, although still very low by world standards, has also been rising (from 15 GJ in 1980 to 20 GJ in 1998).

Greenhouse gas emissions

Emissions of the three most important greenhouse gases totalled almost 1000 million tonnes of CO_2 equivalent in 1990. Of these carbon dioxide is the most significant, representing 53 % of the total, with methane accounting for a further 39 %. Fuel combustion is responsible for 95 % of all carbon dioxide emissions, with the remaining 5 % coming mostly from industrial processes. The major sources of methane are agriculture and waste disposal.

Table A2.3 1990 greenhouse gas emissions inventory for India (kt)

	CO_2	CH_4	N_2O
Total fuel combustion	508600		11
Energy Industries			
Manufacturing Industries and Construction			
Transport	*57300*		
Other Sectors			
Emissions from biomass	*300460*	*1579*	*11*
Total fugitive emissions from fuels		2535	
Total industrial processes	24200		1
Total agriculture		12654	243
Enteric fermentation		*7563*	
Manure management		*905*	
Rice cultivation		*4070*	
Agricultural soils			240
Prescribed Burning of Savannahs			
Field Burning of Agricultural Residues		116	*3*
Total land-use change & forestry	1485		
Total waste		3288	
National total	532800	18477	255

Future trends in energy use and CO_2 emissions

Projections for India by the US Energy Administration assume that GDP in India will grow by 5.2 % per year over the period 2000 to 2010 to reach $750 billion. Furthermore it is expected that GDP per capita will increase to $570 by 2010, still very low by world standards. Energy use is also projected to increase, by 4.0 % per year, to reach 22000 PJ by 2010 and carbon dioxide emissions are expected to exceed 1400 million tonnes by the same year.

INDIAN ATTITUDES TOWARDS THE CDM

The Indian government believes that the design of the CDM should not in any way compromise the modification of longer-term trends in emissions and should be consistent with the objectives of the Convention. It also holds that:

- any reduction in greenhouse gases must be real and measurable;
- the use of the mechanisms should be supplemental to domestic action.
- the CDM must be designed such that it delivers benefits to developing counties in terms of national environmental and development goals;
- any investment under the CDM should be additional to the investing country's overseas development assistance;
- the CDM approach must be project by project.
- cleaner technologies made available must be state of the art.
- indicators or criteria should be drawn up with which to help assess the sustainability benefits of the CDM.

OPPORTUNITIES FOR CO_2 MITIGATION

Introduction

This section provides an overview of energy use in the different sectors of the Indian economy and identifies a range of greenhouse gas abatement options in each sector, for later CDM screening.

Power sector

At the end of March 1998, India had an installed electricity generating capacity of 89.1 GW, producing 420 TWh of electricity for the year 1997/98. This capacity consisted of 64.2 GW of thermal plant (mostly coal), 21.9 GW of hydro (of which 155 MW was small hydro), 2.2 GW of nuclear and 0.9 GW of wind.

The Indian power sector is undergoing rapid expansion with 16.7 GW having been added over the period 1992 to 1997 of which 14.5 % was hydro and the rest being mostly thermal and nuclear plant.

CO_2 mitigation options

Opportunities for CO_2 mitigation in the power sector centre on reducing the proportion of coal in the generation and better utilisation of that which remains.

Renovation of coal fired plant	Around 30 GW of existing coal-fired plant is in need of some form of renovation and modernisation that could increase the output by the equivalent of 5 GW of new capacity.
Coal washing	The ash content of Indian coal has been increasing over time and consequently power stations have been using coal with a higher ash content than for which they were designed. This adversely effects performance by decreasing boiler efficiency, increasing auxiliary consumption and lowering availability. Coal washing can reduce the ash content of coal from 40 % to 31 %, improving the heat value from 15 GJ/tonne to 19 GJ/tonne.
Clean coal technologies	Coal is likely to remain the most important fuel for electricity generation for the foreseeable future. New conventional coal-fired power plants have an efficiency of around 38 %, whereas clean coal technologies such as PFBC and IGCC can achieve efficiencies of 40 – 45 %, with commensurate reductions in pollutant emissions.

CCGT Advancements in gas turbine manufacture, together with environmental concerns, have made CCGT plant attractive for electricity generation in India. However, a wide gap is likely between the domestic supply of gas and its potential demand unless major gas discoveries are made. LNG imports are a further possible source of fuel.

Large hydro Only 20 % of India's potential for large-scale hydropower is current exploited and additional capacity could help meet the rapidly increasing demand for electricity without increasing CO_2 emissions.

Small hydro Only 35 % of rural households have access to electricity and small hydropower (<3 MW) is one way of meeting the need of these people for electricity without increasing CO_2 emissions.

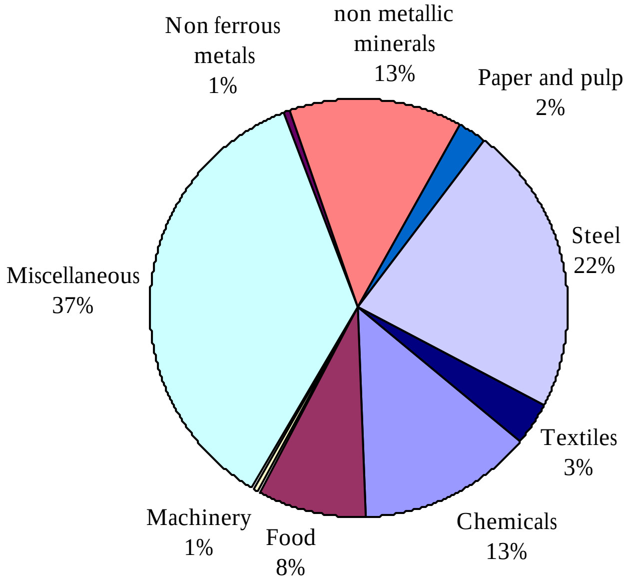
Wind Currently, installed wind power capacity is only about 4 % of the potential. Additional capacity could produce sizeable amounts of electricity in synchronisation with the electricity grid

PV There is a large potential for PV in India and such power plants will be needed in the longer term if India is to meet its electricity needs in a sustainable way. PV is particularly suited grid-stabilisation applications in rural areas. Although, in the short term (up to 2010) this technology is likely to be at a demonstration stage.

Industry

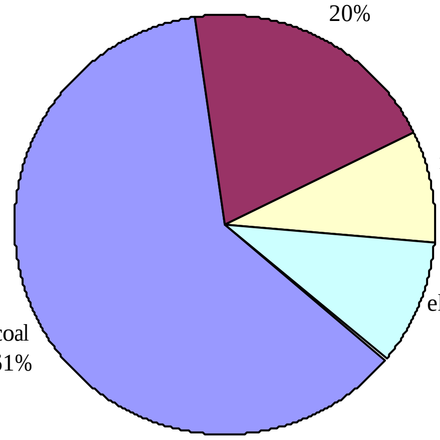
The breakdown of energy consumption between the major manufacturing sectors in India is shown in Figure A2.2. The steel industry dominates consumption at 906 PJ per year and represents around 22% of the total annual consumption of 4,050 PJ in all of manufacturing. Chemicals manufacture and non-metallic mineral products are also important each representing around 13% of total industrial consumption (approximately 535 PJ per year each). A further important sector is food, which consumes around 10% of all industrial consumption mainly in sugar manufacturing. Paper and pulp and textiles together consume around 6% of total industrial energy at approximately 230 PJ.

Figure A2.2 Breakdown of energy use by sub-sector in manufacturing industry



The pattern of fuel use in industry is shown in Figure A2.3. Almost 62% of total fuel use is coal with a further 20% oil products. Electricity is around 10% of supplied energy with the remainder, of 8%, natural gas. Compared with the total final fuel consumption in the country, coal is exclusively used in industrial processes as is natural gas, with only 4% used elsewhere in the economy. Industrial use of oil products represents around 27% of total usage and electricity approximately 38%. The Indian industrial economy is dominated by coal use.

Figure A2.3 Breakdown of fuel use in manufacturing industry



The Steel Industry

As previously pointed out the iron and steel industry is the largest consumer of energy in the industrial sector. As in most developed steel industries there are two production routes – the integrated route, which produces steel from crude ore and the electric arc furnace (EAF) route, which recycles steel scrap. Total steel production in India is around 26 Mt per year of crude steel with 9-10 Mt via the recycling, EAF route. The overall efficiency of steel production in India is around 35 GJ/tonne crude steel, which compares with 25 GJ/tonne crude steel in western Europe. There are seven integrated steel plants in India and, in the early eighties there were 270 EAF furnaces. At end of the nineties a significant number of these are no longer in operation.

Although substantial energy conservation measures have been adopted in India, the performance of the integrated steel plants is poor compared to other countries. Efforts are in progress to reduce energy consumption further by importing good quality coking coal, phasing out open hearth furnaces for steel making which are now obsolete in the West and introducing more continuous casting which offers significant energy savings.

The Minerals Sector

This sector is dominated by cement manufacturing. India is the third largest cement producing country in the world, with a current capacity of approximately 96 Mt per year and a current annual output of around 70 Mt. In spite of the rapid growth in the industry, the per capita consumption of cement in India is still one of the lowest in the world. There are about 100 large cement plants in the country and about 250 mini-plants, mainly vertical shaft kilns. In the past four to five years most cement sites based on wet kiln processes have been converted into

more energy efficient and environmentally friendly dry process plants. Currently it is estimated that approximately 84% of cement production is via large scale dry processes.
Estimates of the specific energy consumption, in the country, indicate 4.9 GJ/tonne of cement, which compares with a typical SEC for dry processes in western Europe of 3.5-3.9 GJ/tonne. The current efficiency of recent dry process kilns is therefore relatively low.

The cement industry has recently been de-licensed. This means that private parties can now set up cement plants in various areas, as long as they meet the required environmental standards. The Government of India is trying to meet the high standards by suggesting the setting up of several coal washeries around the country to meet the high standards of low ash cement coal. The de-licensing has increased investment and has led to much of the dry process conversions evident over the last few years.

Chemicals

The chemicals industry energy consumption is dominated by fertiliser manufacture which is estimated to consume 207 PJ per year of the total 535 PJ per year in all chemicals production. The chlor-alkali industry, which produces caustic soda and chlorine is also important although this is estimated to consume only around 7-8 PJ delivered energy (mainly electricity).

India operates approximately 40 nitrogen fertiliser plants and ranks as the fourth largest producer in the world, with an ammonia production capacity of 8.5 Mt. The share of phosphatic fertilisers is insignificant and India does not produce potash based fertilisers. Nitrogen based fertiliser can use a wide range of feedstocks, including coke oven gas, naptha and increasing levels of natural gas. The increase in the capacity utilisation of the fertiliser industry in the mid-1990’s was mainly as a result of better capacity utilisation of natural gas based plants, due to the newly found reserves of natural gas.

Recent advances in process technology and catalysts have resulted in lower energy intensities in recent years and de-licensing of the industry has led to further investments. Government recommendations from the Fertiliser Pricing Policy Review Committee include:

- De-regulation.
- Feedstocks to be developed away from less efficient sources.
- Promotion of a balanced use of fertiliser and new pricing policies.
- Lower gas prices should be reflected in lower fertiliser pricing.

Chlor-alkali produces caustic soda and chlorine by the electrolysis of sodium chloride. In India, the caustic soda industry began with the diaphragm electrolytic cells, which has a high energy cost and produces an inferior quality product. However, pollution problems are lower with diaphragm cells. Mercury cells are now widely used as they consume less power and produce a more concentrated liquor. However, heavy metal pollution, due to the presence of mercury, is an effluent hazard. Newer membrane cell technologies are more energy efficient and now represents around 30% of total production. There is still significant scope for introducing further membrane plants. However, capital costs are relatively high.

Other Sectors

India is the world’s largest producer of sugar and sugar cane and there are presently 465 sugar mills in operation producing nearly 14.5 Mt per year of product. Energy consumption is estimated at 340 PJ per year, which represents between 8 and 9% of total industrial energy consumption. Sugar is extracted from sugar cane and the process consists of: separation of juice from the fibre -(milling process), clarification and removal of impurities, removal of water, crystallisation and finally drying and separation. There are two processes for clarifying the juice – sulphitation and carbonation. The latter process requires heat but currently produces a superior product. The technologies adopted in many of the sugar factories in India are outdated, as more than half of the factories are over 25 years old. Hence there is considerable scope for retro-fitting state of the art technologies, including improved sulphitation processes.

The pulp and paper industry consumes an estimated 2.5% of total industrial energy consumption (98 PJ per year) and has a capacity of around 4 Mt per year in around 380 pulp and paper mills. Low capacity utilisation in the industry is because of acute shortages of raw material, fuel shortages and variable markets. India's per capita paper consumption is only 3.6 kg per year as compared to the world's average of 46 kg per year.

The average annual production capacity of a plant in India is only around 10 kt per year compared with developed country mill capacities of around 50 kt per year. The reason for the current low production utilisation is therefore also associated with high production costs because, in comparison with larger mills which are more efficient, smaller mills do not have chemical recovery systems and electricity co-generation thus creating high production costs.

The textiles industry is estimated to consume around 3.5% of total industrial energy (135 PJ per year) and in order to maintain competitiveness in a world market, the industry uses modern mill technologies. There is nevertheless significant scope for the industry to improve its efficiency further through the use of cost effective process improvements, particularly associated with textile finishing. These are often highly cost effective.

The installed capacity of primary aluminium smelting is currently at around 625 kt per year, although current tonnage output is only approximately 450–500 kt per year. At present there are five smelting plants and although Indian companies have taken measures, in recent years, to reduce specific power consumption, it is still significantly higher than the international averages. This currently stands at around 58 GJ (electricity)/tonne of aluminium compared with a typical western European level of 54 GJ/tonne.

Greenhouse Gas Mitigation Options

The following sections outline some other key areas and technologies for improving the energy use and emissions levels in India's industrial sector. The sectors are described under three headings of metals, mineral products and others

Metals

Iron & Steel Blast furnace coal injection. The replacement of coke in blast furnaces by coal injection, removes the need for coke manufacture with its associated high energy use and pollution. This technique is becoming wide-spread throughout the world and has applications in India.

Replacement of open hearth steel-making. Phasing out open hearth steel making in favour of basic oxygen furnaces offers large potential energy savings and improved environmental conditions. Oxygen steel making is now standard in most developed steel industries and is limited only by capital investment requirements.

The use of ‘off-gases’ from blast furnaces and basic oxygen furnaces as a boiler fuel and for use in direct electricity generation (‘top gas’ turbines on blast furnaces) is found in many modern integrated steel plants. Increasing the collection of blast furnace gas can often be highly cost effective as long as there is use for the fuel on site or nearby.

Continuous casting of steel replaces a heating and rolling stage in steel forming, by casting directly into slabs and billets. The conversion to continuous casting has benefits other than energy savings alone, including increased production, potential labour saving and quality improvements.

There are also a wide range of other cost effective measures possible on steel plants including improvements to boilers, furnaces, electric motors and rolling plant, which can significantly improve energy and process efficiency across most steel plant activities.

Primary Aluminium New smelting processes offer potential energy savings of between 15-20% but many are still at the development stage. New smelting techniques could be made available to Indian industry, but investment levels are likely to be high and processes may be better piloted in the developed world.

Best practice in the standard Hall-Heroult process can achieve significant energy savings and include techniques such as automatic feed facilities, automation and mechanisation of cell operations, improved cathode linings and cell designs, reduced voltage losses by optimising electroliser designs, more efficient gas cleaning equipment.

Mineral Products

Cement - small plant General renovation projects including mechanisation of vertical shaft kilns increasing capacity and levels of energy efficiency.

Raw material grinding improvements including, roller grinders and improved motors. Also the use of more efficient roller grinders for the clinker grinding stage.

Improving the fabric of vertical kilns by optimising kiln size and shape and using improved refractories and insulation materials.

Cement - dry process Most wet processes have now been converted to dry. However, there is still scope for improvement to dry process operations, which includes more significant changes such as pre-calciner kilns and lower cost high efficiency and high velocity burners and improved heat recovery. Some of these options often require fundamental kiln design changes.

Grinding improvements – this can include a range of technologies including high efficiency separators and roller mills and pre-crushing systems for both raw materials and final clinker. These have also been pointed out as important to smaller cement sites.

Computerised process control systems. There are now sophisticated control systems for managing kilns and raw material operations and these are becoming internationally available as proprietary control packages.

Other minerals There are a wide range of cost-effective measures for improving glass manufacturing, brick making and other ceramics manufacturing processes. These are mainly associated with kiln and furnace improvements and include measures such as improved burners and heat recovery, enhanced control systems and better raw material preparation and control. Some of these have already been discussed in connection with opportunities in China where their scale of contribution is likely to be higher than in India.

Other sectors

Sugar Bagasse is waste-product of sugar manufacture and can be used to generate electricity and heat in a cogeneration plant, reducing the use of fossil fuels. There are at least 420 sugar mills that have been identified as being suitable for bagasse-based cogeneration, with a potential of 3,500 MW.

Improved sulphitation process for juice clarification as described previously.

Improved evaporation techniques to reduce energy use, including multi-effective and falling film evaporators

Improved centrifuging techniques including continuous centrifuges.

Paper & Pulp Capacity management is a key energy saving opportunity for paper and pulp manufacture. Present mills are small compared to international operations and utilisation is low. Rationalisation of the industry will improve efficiency and will allow chemical recovery and CHP systems to be installed more cost effectively.

Liquor recovery from pulping operations can be used to fire “black liquor“ boilers to generate steam in CHP schemes and for other process heating purposes. This is widely practised in larger paper mills and has potential in India.

Alternative bleaching systems as an alternative to chlorine based systems are now available and use lower levels of energy and significantly improve chemical effluent.

Drying systems in paper mills use considerable amounts of heat energy and there are wide range of techniques available to improve energy consumption. These include increased paper pressing, improved humidity control in drying hoods and alternative schemes such as airless drying and direct infra-red systems.

CHP is used in most developed country large paper mills and allows significant energy savings in paper mill operations. The size of plant is crucial to the cost effectiveness of a CHP scheme and is more suited to medium to large mills.

Chemicals Fertiliser plant improvements are a significant option for energy savings. Options include recovery of process gases and emitted hydrogen, waste heat recovery and improved heat transfer efficiencies and the introduction of 'closed cycle' heating and cooling water systems.

In the chlor-alkali industry, the continuation of replacement of diaphragm and mercury cells with newer membrane technologies offers a significant potential for further savings. However, this is generally dependent upon plant replacement cycles rather than being cost effective as a shorter term replacement technology.

Residential sector

The number of households increased by 24 % over the period 1981 to 1991 to reach a total of 152 million. Traditional fuels such as firewood, dung-cakes and agricultural residues are still the most common energy sources in the residential sector, particularly in rural areas. However, the use of traditional fuels is decreasing as these are being increasingly substituted by more efficient commercial fuels. The consumption of total commercial energy by households (largely urban) increased at a rate of 8.1 % per annum over the period 1981 to 1991. Among commercial fuels, petroleum products in the form of kerosene and LPG account for nearly two-thirds of consumption, with electricity only representing 10 %.

In rural areas it is estimated that cooking accounts for over 90 % of total fuel use with around 200 million tonnes of fuelwood, 100 million tonnes of dung-cake and 100 million tonnes of non-fodder crop residues consumed as fuels every year. The consumption of energy for lighting is very low, since the majority of households use kerosene lamps.

Mitigation options

There are opportunities in the domestic sector to improve the end-use efficiency of both traditional and commercial fuel use and to use harness renewable sources of energy in modern applications.

CFLs CFLs are more up to four times more efficient than conventional incandescent lighting and can be used to reduce demand for electricity, so helping to bridge the supply-demand gap that is a feature of electricity supply in India.

Improved chulhas Improved cook stoves (chulhas) have an efficiency of between 20 and 30 %, compared to 10 % for conventional chulhas. A programme begun in 1984/85 has already resulted in 28.5 million improved chulhas being used, however, this leaves a further 40 million households still using conventional chulhas.

Solar water heaters Solar water heaters can be used to replace electric geysers so saving electricity. At the moment ownership of electric geysers is small, but growing very rapidly amongst richer households.

Transport

Transport is a rapidly growing sector of the Indian economy and is now the second largest consumer of energy next to industry. Over the period from 1980 to 1998, transport energy use more than doubled to reach a total of 2400 PJ. Not surprisingly, oil products in the form of diesel and petrol are the dominant fuels, accounting for 90 % of total energy use.

Since the 1950s, India has moved from being a rail dominant economy to one primarily dependent on road transport. Furthermore the railways are now mainly a passenger operation rather than one for freight. The inadequate public transport system has also led to an increase in the use of personalised modes of transport.

Mitigation options

Mitigation options in the transport are focussed on improving the fuel efficiency of vehicles in use, through both technological advances and by creating better operating conditions.

New technology	Modernisation of road vehicles could significantly enhance their fuel efficiency. Some progress has been made for cars, but considerable improvement is possible for 2/3 wheelers, trucks and buses.
Driver training and improved maintenance	It has been estimated that improved driver training, plus better-trained mechanics could improve fuel efficiency by 10 %.
Traffic management	Even with existing road vehicles, fuel efficiency could be significantly improved with better-regulated operating conditions. The lack of footpaths and cycle ways coupled with non-transport use of the road (hawkers, stacking of materials, parking etc) result in congested roads and the slowing of traffic, causing fuel consumption to rise.

TECHNO-ECONOMIC SCREENING

The CO_2 mitigation options identified in the previous section have been ranked by their cost of abatement to generate an emission reduction cost-curve for India as shown in Figure A2.4. The major options in each sector are also summarised in Table A2.4.

This shows that mitigation options that have been identified save a total of 470 Mt of CO_2 over the period to 2010, of which nearly 250 Mt are calculated to be cost effective. This compares with forecast CO_2 emissions in 2010 of 1400 Mt.

Opportunities that can have a large potential for saving CO_2 and are cost-effective include CCGTs and coal washing in the power sector, low cost improvements in steel, improved grinding and control systems in cement and bagasse cogeneration in sugar. Smaller cost effective contributions are also available from CFLs and improved cooking stoves in the domestic sector and driver training and improved maintenance of freight vehicles in the transport sector.

Figure A2.4 CO_2 cost-abatement curve for India

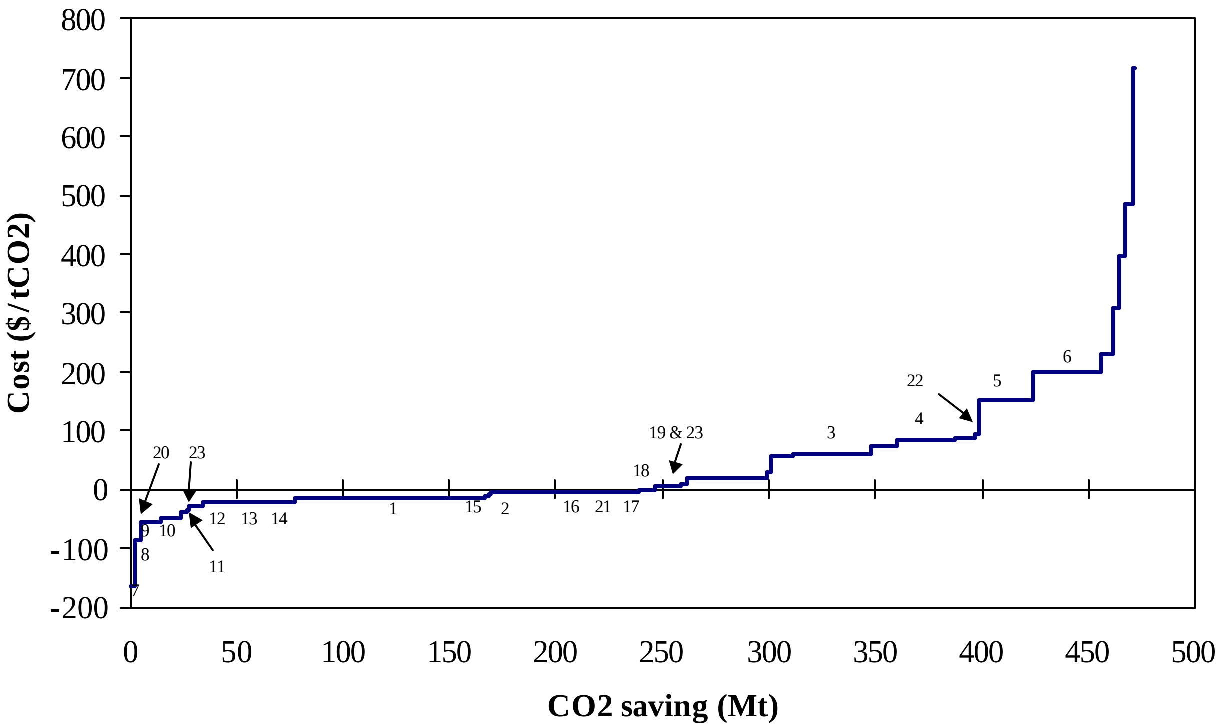


Table A2.4 Summary of the CO_2 savings and cost of abatement for India

Key	Option	CO_2 saving $MtCO_2$	Cost of abatement ($/tCO2)
	Power		
1	CCGT	89.40	-13
2	Coal washing	35.68	-6
3	Small hydro	25.03	60
4	IGCC	27.08	86
5	Renovating existing plant	24.58	151
6	Wind	32.30	200
	Industry		
7	Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	2.79	-150 to -200
8	Capacity management in paper and pulp	2.28	-85
9	Improved grinding in cement	7.17	-55
10	Low cost improvements in steel	9.58	-45 to -50
11	Aluminium smelting best practice	1.44	-35 to -40
12	Continuous casting	5.03	-22
13	Control systems in cement	34.40	-21
14	Fertiliser plant improvements	3.16	-20
15	Process improvements in sugar	3.84	-10 to -38
16	Bagasse cogeneration in sugar	11.20	-4
17	Low cost measures in other sectors	16.52	-3
18	Replace open hearths for steel	7.71	0
19	Low cost measures in chemicals	11.86	8
	Domestic		
20	Improved chulhas	1.81	-55
21	Compact fluorescent lightbulbs	6.52	-4
22	Solar water heaters	1.77	94
	Transport		
23	Driver training and improved maintenance	6.62	-26
24	Traffic management	2.52	8

ENVIRONMENTAL, SOCIAL AND DEVELOPMENT SCREENING

Power sector

In the power sector, CO_2 mitigation options have been assessed in comparison with a baseline represented by a pulverised coal-fired plant.

CCGT Compared to coal plant, CCGTs have lower emissions of SO_x and do not have problems associated with waste disposal.

Coal washing Coal washing will improve the generation efficiency of coal power stations so reducing emissions of non-greenhouse gas pollutants, helping to improve local air quality.

Small hydro Small hydro is a clean source of electricity generation and so can help improve local air quality compared to fossil alternatives. In rural areas the provision of electricity can improve irrigation, so stimulating rural development and helping to reduce poverty. India has a well developed small hydro manufacturing capability and so there may be employment benefits in this sector.

IGCC The higher efficiencies of IGCC plant will reduce emissions of non-greenhouse gas pollutants and the quantity of ash will be greatly reduced per unit of output compared to pulverised coal power stations.

Renovation of exiting plant Upgrading existing coal plant will enable higher efficiencies to be achieved and so produce more electricity for the same coal burn. This will help defer the need for new coal capacity and so will help reduce emissions of other pollutants such as sulphur and nitrogen oxides and particulates.

Wind Compared to coal-fired generation wind power will reduce emissions of all pollutants.

Table A2.5 Summary of sustainability impacts of potential CDM options in the power sector

	CCGT	Coal washing	Small hydro	IGCC	Upgrade existing plant	Wind
Environmental impacts						
Air quality	+	+	+	+	+	+
Water quality	0	+	+	0	0	+
Flood prevention	0	0	0	0	0	0
Soil conservation	0	0	0	0	0	0
Solid waste	+	+	+	+	+	0
Noise	0	0	0	0	0	0
Biodiversity protection	0	0	0	0	0	0
Social and development benefits						
Employment	0	0	+	0	0	0
Rural development	0	0	+	0	0	0
Poverty reduction	0	0	+	0	0	0
Benefits to key groups	0	0	0	0	0	0

Industry

The following tables summarise the sustainability benefits of the most significant greenhouse gas mitigation options in the industrial sector. The measures identified have already been assessed as being cost effective from the cost abatement curve analysis described previously.

Replacing open hearths in steel making	Replacing open hearths in steel making. Transfer of production to cleaner basic oxygen steel making offers a significant improvement in both local and global air quality and is likely to improve waste arisings. Since this technology is only applicable to integrated steel plants there is unlikely to be benefits for rural development. However, efficiency improvements in steel making (open hearth conversions represent one of the most important opportunities) ultimately could lead to improvements in employment and to the overall potential economic growth of the country. Open hearth furnaces are a primitive way of manufacturing steel, which have been obsolete in the west for at least 30 years because of its inefficiency and the high levels of pollution.
Continuous casting of steel	Continuous casting of steel is an important technology particularly in reducing energy consumption and in improving quality and mechanisation in larger steel plants. The effects on employment are therefore likely to be negative and there is little additional social and developmental benefit, particularly at the rural level, from the further development of this technology. From a national economic perspective, improvements in steel making are nevertheless, likely to have a positive effect on economic growth.
Low cost improvements in small-scale steel manufacturing	In small scale steel manufacturing, low cost efficiency improvements will also have a significant effect on local air quality and on local employment and rural development prospects. The local environment, particularly with regard to waste arising and, in some cases, preservation of water quality is also likely to be important.
Aluminium smelting improvements	Whilst a large potential energy saving opportunity with resulting improvements in global and air quality, smelting is centred in only five sites across India. Employment benefits may improve in the specific regions. However, the effect on overall rural development and poverty reduction would remain unaffected.
Improved control on cement kilns	Improved control on large dry cement kilns has been identified as offering one of the largest potentials for greenhouse gas abatement and is highly cost effective. However, greenhouse gas savings and local air quality improvements are likely to be the only resulting benefit. There is likely to be little social and developmental benefit from the application.
Improved grinding in cement	Improved grinding systems for cement plant will benefit energy use and local air quality because of improved control within the process and will aid water quality and solids waste levels because of reduced effluent problems and waste dumping. Since this technology is only likely to be adopted in larger, dry process works, the rural development benefits and poverty reduction aspects of such a measure will not be significant.
Bagasse cogeneration in sugar	Since bagasse does not contain any sulphur and has an extremely low ash content, then using it to replace coal use electricity and heat generation will improve local air quality.

Process improvements in sugar	Process improvements in sugar mills benefit air quality from reduced combustion emissions, particularly in boilers, and benefit both employment and rural development since sugar collection and mills are normally distributed across rural areas. There is also likely to be benefits in local poverty reduction.
Capacity management in paper and pulp	Paper and pulp manufacturing capacity management offers global air quality improvements and local environment benefits such as improved water quality and reductions in waste. Rationalising production into more efficient plants is also likely to improve employment prospects, but is likely to have a negative impact on rural development because of the need to consolidate production into larger more efficient mills.
Renovation of small-scale fertiliser plants	Renovation of small scale fertiliser plants, in addition to energy saving, will improve local air quality and is likely to have a positive effect on local employment and rural development. The Indian Government is urging efficiencies in fertiliser manufacture and this is likely to be concentrated on the rationalisation of the industry towards larger plants using natural gas as feedstock. The effect on rural development of such policies is likely to be negative.
Low cost improvements in chemicals	Low cost improvements in chemicals manufacture, particularly in smaller chemicals plants have benefits in local air quality and improve prospects for employment and rural development.
Low cost improvements in other sectors	Low cost process improvements in textiles, plastics and wood are likely to save energy and will also benefit social development in rural areas, particularly where plants are outside centres of major population.

Table A2.6 Summary of sustainability impacts of potential CDM options in industry – (1)

	Replace open hearths in steel	**Low cost improvements in steel**	**Continuous casting of steel**	**Aluminium primary smelting improvements**
Environmental impacts				
Air quality	+	+	+	+
Water quality	0	+	0	0
Flood prevention	0	0	0	0
Soil conservation	0	0	0	0
Solid waste	+	+	0	0
Noise	0	0	0	0
Biodiversity protection	0	0	0	0
Social and development benefits				
Employment	+	+	-	+
Rural development	0	+	0	0
Poverty reduction	0	0	0	0
Benefits to key groups	0	0	0	0

Table A2.7 Summary of sustainability impacts of potential CDM options in industry – (2)

	Dry cement process control	Improved grinding systems for cement	Bagasse cogeneration in sugar	Sugar process improvements
Environmental impacts				
Air quality	+	+	+	+
Water quality	0	+	0	0
Flood prevention	0	0	0	0
Soil conservation	0	0	0	0
Solid waste	0	+	+	0
Noise	0	0	0	0
Biodiversity protection	0	0	0	0
Social and development benefits				
Employment	0	0	0	+
Rural development	0	0	0	+
Poverty reduction	0	0	0	+
Benefits to key groups	0	0	0	0

Table A2.8 Summary of sustainability impacts of potential CDM options in industry – (3)

	Paper and pulp capacity management	Low cost improvements in chemicals	Fertiliser plant renovation	Low cost improvements in textiles, plastics & wood
Environmental impacts				
Air quality	+	+	+	+
Water quality	+	+	0	0
Flood prevention	0	0	0	0
Soil conservation	0	0	0	0
Solid waste	+	0	0	0
Noise	0	0	0	0
Biodiversity protection	0	0	0	0
Social and development benefits				
Employment	+	+	+	+
Rural development	-	+	+	+
Poverty reduction	0	0	0	0
Benefits to key groups	0	0	0	0

Residential

The sustainability benefits of the mitigation options identified for the residential sector are summarised below.

CFLs CFLs can reduce emissions of non-CO2 gases from electricity generation. Most poorer households in India do not use electricity for lighting and so there is unlikely to be much impact on poverty

Improved chulhas Improved chulhas can reduce the depletion of woody biomass, so helping to prevent soil erosion and protect biodiversity. Local air pollutants such as particulates may also be reduced. The greater efficiency of the stoves should mean less time is spent collecting fuelwood and this should particularly benefit women.

Solar water heaters The use of solar water heaters will reduce emissions of non-greenhouse gases from electricity generation. As they are most likely to be installed in richer households there are unlikely to be any poverty reduction benefits. However, if locally made then there could be a positive impact on employment.

Table A2.9 Summary of sustainability impacts of potential CDM options in the residential sector

	CFLs	Improved Chulhas	Solar water heaters
Environmental impacts			
Air quality	+	+	+
Water quality	0	0	0
Flood prevention	0	0	0
Soil conservation	0	+	0
Solid waste	0	0	+
Noise	0	0	0
Biodiversity protection	0	+	0
Social and development benefits			
Employment	0	0	+
Rural development	0	0	0
Poverty reduction	0	+	0
Benefits to key groups	0	+	0

Transport

The major sustainability impacts of key measures identified in the transport sector are as follows.

Driver training and improved maintenance	Improved driver training and better maintenance will reduce fuel consumption and lower the emissions of pollutants such as NO_x, VOCs and particulates, so improving urban air quality. Additional mechanics may be needed to carry out the improved maintenance program thus creating more jobs.
Traffic management	In addition to air quality improvements, improved public transport should benefit key groups who depend on these services.

Table A2.10 Summary of sustainability impacts of potential CDM options in the transport sector

	Driver training and improved maintenance	Traffic management
Environmental impacts		
Air quality	+	+
Water quality	0	0
Flood prevention	0	0
Soil conservation	0	0
Solid waste	0	0
Noise	0	0
Biodiversity protection	0	0
Social and development benefits		
Employment	+	0
Rural development	0	0
Poverty reduction	0	0
Benefits to key groups	0	+

PRIORITISATION OF KEY CDM OPPORTUNITIES IN INDIA

The following table summarises the key CDM opportunities in India, scoring them on the cost of mitigation, their potential for reducing emissions and their contribution to sustainable development through bringing other environmental and social and development benefits.

Summary of possible CDM opportunities identified in India

Opportunity	Mitigation cost	Greenhouse gas reduction potential	Other environmental benefits	Social and development benefits
Power				
CCGT	***	***	**	*
Coal washing	***	***	**	*
Small hydro	*	***	***	***
IGCC	*	***	**	*
Renovating existing coal plant	*	***	*	*
Wind	*	***	**	*
Industry				
Low cost measures in low intensity sectors such as textiles, engineering, and miscellaneous small industries	***	*	*	**
Manage capacity in paper & pulp	***	*	***	*
Improved grinding in cement	***	*	***	*
Low cost improvements in steel	***	**	***	**
Improved aluminium smelting	***	*	*	*
Continuous casting in steel	***	*	*	*
Control systems in cement	***	**	*	*
Fertiliser plant improvements	***	*	*	**
Process improvements in sugar	***	*	*	***
Bagasse cogeneration in sugar	***	**	**	*
Replace open hearths for steel	**	*	**	*
Low cost measures in chemicals	**	**	**	**
Domestic				
Improved chulhas	***	*	***	**
Compact fluorescent lightbulbs	***	*	*	*
Solar water heaters	*	*	**	*
Transport				
Driver training & better maintenance	***	*	*	*
Traffic management	**	*	*	**

From this table the following conclusions are drawn:

- The power sector offers the largest potential to reduce emissions of CO_2 and some of the options, most notably coal washing and combined cycle gas turbines for electricity generation can be highly cost-effective. The use of renewables, such as small hydro and wind, while being more expensive as a means of CO_2 reduction offer many sustainability benefits.
- Manufacturing industry is another sector in which many of the CO_2 mitigation options are cost effective, although the savings are typically smaller than in the power sector. However, the sustainability benefits associated with these opportunities can be substantial and particularly attractive options include low cost improvements in steel and cement-making and process improvements in sugar manufacturing.
- The domestic and transport sectors also offer cost-effective greenhouse mitigation options, albeit on a smaller scale than either the power sector or industry. These options can also have important sustainability benefits and improved cooking stoves (chulhas) have been identified as being particularly attractive.
- Many of these options can contribute to the development objectives laid out in the Nine Five-Year plan which included improved coal utilisation technologies, fuel switching from coal to gas, promotion of renewable energy resources and improved transport infrastructure.

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Appendix 3
South Africa case study

South Africa Case Study

INTRODUCTION

This case study describes the work undertaken to identify and prioritise greenhouse gas mitigation opportunities in South Africa that might be suitable for funding under the Clean Development Mechanism. It is divided into the following sections:

- Country profile
- National development objectives
- Energy and greenhouse gas emissions
- South African attitudes towards the CDM
- Overview of opportunities for CO_2 mitigation
- Techno-economic screening of mitigation options
- Environmental, social and development screening of mitigation options
- Prioritisation of potential CDM opportunities

COUNTRY PROFILE

Population

In 1999 the population of South Africa was estimated at 43.5 million and the current growth rate is around 1.3 % per annum.

Economy

South Africa's economic growth has been sluggish in recent years, with real gross domestic product (GDP) growth estimated at only 0.5% in 1999. However, this is an improvement from the early 1990s, when the growth rate was negative.

The poor performance of the economy, combined with a growing population means that there has been a decline in the growth of GDP per capita from about 3 % per annum in the 1960s to an average negative growth rate of 1 % during the 1990s. Consequently GDP per capita, which is about $3,200, is little changed from the level of 30 years ago.

As with many countries, the importance of the service sector has been growing over the last 20 years and it now contributes just over half of total GDP, with industry accounting for 42 % and agriculture 7 %.

Society

South African society is characterised by a wide gulf in living standards between different sections of the population. While average incomes amongst the white population are close to that of western Europe, the black community which make up the bulk of the population, is little richer than the rest of sub-Saharan Africa.

One of the biggest problems current facing South Africa is its high unemployment rate, which is currently around 30 %.

Energy resources

South Africa is well endowed with natural resources including energy. Coal is the country's most important fuel and South Africa is the world's third largest coal exporter. Recoverable coal reserves, which are mainly bituminous with relatively high ash content and low sulphur content have been estimated at 55 billion tonnes, equivalent to 250 years production at 1997 levels.

Oil and gas reserves are more limited than those of coal. Proven oil reserves amounted to 29 million barrels at the beginning of 1999, while proven gas reserves total 22 billion cubic metres,

The most widely used renewable energy source in South Africa is fuelwood, which meets the daily energy needs of more than one-third of the country's population. Deforestation attributed to increased fuelwood consumption by a growing population has prompted interest in other renewable energy sources, particularly solar, as South Africa is one of the most favourable locations in the world for solar energy applications. The annual 24-hour solar radiation average is 220 W/m^2.

Wind electricity generation is currently very small. Wind speeds are high variable over the country. The theoretical wind energy resource has been estimated at about 480 MW, but in most regions away from the coast wind speeds are only 6-7 m/s. Water pumping is the only widespread application at the moment, with over 250,000 farm windmills installed nationwide.

South Africa produced just over 3,300 GWh from hydro sources in 1996, two-thirds of which was from pumped storage. The seasonal flow of rivers, and frequent droughts or floods, limit the exploitation of this technology. Some farmers in rural areas use micro-hydro schemes.

DEVELOPMENT PRIORITIES

On coming to power in 1994, the new South African government set up a macro-economic policy, known as Growth, Employment and Redistribution (GEAR). This policy informs the government's attitude towards other initiatives and projects that are planned for the country. Salient features of GEAR are:

- An economic growth of 6%
- The creation of 400 000 jobs each year by the year 2000

However, to date economic growth has been considerably less that 6% and jobs have persistently been lost since GEAR came into effect about four years ago. One major emphasis of the current government is the delivery of services particularly to the previously disadvantaged majority of the population. Against this backdrop, any projects or initiatives that benefit disadvantaged sections of South African society and so help to reduce poverty are particularly important.

The government sees the energy sector in contributing to this economic growth and employment creation, as well as providing infrastructure for households. The 1998 White Paper on Energy Policy sets out the following policy objectives for the energy sector:

- Increasing access to affordable energy services;
- Improving energy governance;

- Stimulating economic development
- Managing energy-related environmental impacts
- Securing supply through diversity

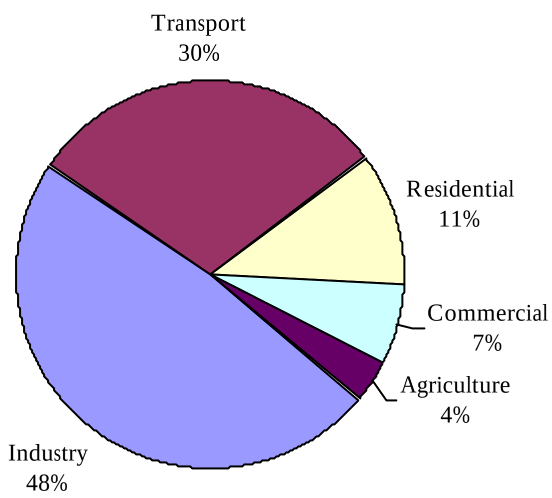
ENERGY USE AND GREENHOUSE GAS EMISSIONS

Energy use

Commercial primary energy use in South Africa is dominated by coal. In 1998 out of a total 4280 PJ of energy, 84 % was coal, 11 % oil, 4 % primary electricity and 1 % gas. Traditional fuels provided a further 480 PJ. Over the period since 1980, primary energy use has been growing at around 3 % per year.

Final commercial energy consumption is dominated by the industry and transport sectors, which together account for 78 %. Residential energy consumption is also significant and represents 24 % of total final energy use, once non-commercial fuels are taken into account.

Figure A3.1 Composition of final commercial energy consumption in South Africa



South Africa's energy intensity is high by world standards and in 1997 was 36 GJ/k$. This compares with a figure of 8 GJ/k$ for the UK in the same year. Energy use per capita is 110 GJ, high for a developing country. However, there are wide disparities between the energy consumption of different sections of society.

Greenhouse gas emissions

Emissions of the most important greenhouse gas emissions in South Africa totalled 365 million tonnes CO_2 equivalent in 1990, of which CO_2 emissions were responsible for 80 %. The energy supply industries are the dominant source of CO_2 emissions, with transport also being significant.

Table A3.1 1990 emissions inventory for South Africa (kt)

	CO_2	CH_4	N_2O
Total fuel combustion	247944	116	12
Energy Industries	*167962*	*6*	*3*
Manufacturing Industries and Construction	*25416*	*4*	*0*
Transport	*31390*	*39*	*5*
Other Sectors	*22216*	*66*	*3*
Other	*960*	*0*	*0*
Total fugitive emissions from fuels	22001	674	
Total industrial processes	23461	4	2
Total agriculture		1064	61
Enteric fermentation		*917*	
Manure management		*83*	*1*
Rice cultivation			
Agricultural soils			*57*
Prescribed Burning of Savannahs		*62*	*2*
Field Burning of Agricultural Residues		*2*	*0*
Total land-use change & forestry	-20614		
Total waste		380	3
National total	293405	2238	78

7.1.1 Trends in CO_2 emissions

Work by ETSU for the Department of the Environment Transport and the Regions has projected that CO_2 emissions in South Africa will increase by an average of 1 % per year to reach 370 million tonnes by 2010. These projections are based on an average annual economic growth of 3 % per year over the projection period.

SOUTH AFRICAN ATTITUDES TOWARDS THE CDM

The South African government supports a CDM that is transparent and leads to sustainable development in developing countries; whilst assisting Annex I country parties to achieve compliance with their quantified emission limitation and reduction commitments. Further the official position is that:

- the CDM should assist developing countries, particularly the very vulnerable, to adapt to the adverse impacts of the global climate change;
- participation in the CDM must be voluntary and inclusive, but also in compliance with the Kyoto Protocol and the Framework Convention on Climate Change;
- CDM projects must be equitably distributed and conform to financial and environmental additionality;
- at least 50 % of Annex I commitments must be met through domestic action, and that the least developed countries should be assisted in capacity building to enable all Parties to participate fully in the Kyoto Protocol;
- funding of projects should be multilateral or bilateral, and should address any imbalances in the regional distribution of CDM activities;

- whilst monitoring and verification should be done under clear guidelines by independent entities, the certification/issuance of certified emission reduction units (credits) must be tracked and undertaken by bodies accredited by COP/MOP;
- there should be strict penalties for non-compliance, including banning from all the mechanisms of the Protocol;
- the adaptation fund must be funded, by levying all mechanisms, with funds equitably distributed;
- the Parties should establish national systems to manage the CDM and the UNFCCC secretariat must provide administrative support to the CDM; and review all operations of the COP/MOP.

Currently, no guidelines exist on how projects will get approval in South Africa. However, it is expected that in the future mechanisms and institutional arrangements will be put in place by the National Committee on Climate Change (NCCC), the consultative and advisory body to the government on issues of global climate change, for an initial technical evaluation of CDM project proposals; prior to final approval for implementation.

One of the major barriers that has been identified as hindering progress on the CDM is the lack of capacity within the country. While elements of academia, business and non-governmental organisations have at least a partial understanding of the CDM, community-based organisations (CBOs) that normally work with the majority of the society at the grass roots level do not have an informed knowledge of the CDM. The general feeling is that for CDM projects and related activities to receive widespread support in the country, there is the need to build and develop endogenous human and institutional capacity.

OPPORTUNITIES FOR CO_2 MITIGATION

Power sector

Total electricity generating capacity in 1999 totalled 41 GW, most of it owned by Eskom, the national utility. Of this capacity, 36 GW was coal; there is one nuclear power plant providing 1.8 GW and hydropower provides a further 2.2 GW, of which 1.6 GW is pumped storage.

Mitigation options

In the power sector there is considerable potential for shifting away from coal to other options that emit less CO_2. However, the huge coal infrastructure in the country is unlikely to be just abandoned. Existing coal-fired capacity is not yet fully utilised and most of Eskom's large power stations are relatively new. The costs of engineering major structural changes in South Africa's generation mix before the end of their useful lives is likely to be prohibitive.

Retrofitting CFBC technology There are 17 large coal-fired power plants in South Africa that have a nominal capacity of 36 000 MW. These plants have an efficiency of about 35% and could be improved by retrofitting circulating fluidised bed combustion (CFBC) clean coal technology is introduced. Various studies have indicated that CFBC is most appropriate for the South African coal.

Gas-fired plant Gas-fired plant could be built using gas from Mozambique, Namibia or Angola. In the short term, the unstable situation in the region makes the prospect of constructing transmission lines across Angola, through Namibia and into South Africa seem remote.

Nuclear Power Eskom favours the development of the 'pebble-bed' reactor rather than the installation of conventional gas-cooled technology. However, no data is available on the cost and performance of this technology.

Wind There is increasing interest in developing small-scale wind farms in South Africa, with the most favourable locations being in coastal areas and in the Drakensberg escarpment. Another favourable use of wind energy is for small-scale utilisation in hybrid applications with PV and or diesel generator sets. Any developments are likely to be small compared with overall electricity capacity.

Biomass The combustion of biomass expressly grown for electricity production could be a future option.

Industry

Industrial energy use in 1998 was 860 PJ of which coal accounted for 44 % and electricity another 40 %. The most significant energy using sectors are iron and steel and mining and quarrying, which together account for about 40 % of the total, with non-ferrous metals and chemicals also important.

Mitigation options

South African manufacturing industry has a history that is very different from other developed industries and as noted above is largely based on a coal/electric economy. Many of the processes used in South Africa differ from those found in Europe and these, whilst sophisticated, are often unfamiliar. As a result, data on CO_2 mitigation options is relatively sparse and so only few options that are generally applicable have been considered.

Cogeneration Eskom has estimated the cogeneration potential at 1200 MW. This option is likely to most attractive if natural gas is available as a fuel.

Energy efficiency in industrial boilers About 5000 small-scale industries in South Africa have boilers, mostly inefficient chain grate stokers that use high-grade coal. Studies by the Department for Minerals and Energy indicate that the efficiencies of these boilers could be enhanced by 10-15% using appropriate retrofits, such as bubbling fluidised bed combustion.

Improving the efficiency of the Lurgi gasifier Sasol produces synthetic liquid fuels and gas using the Synthol process and this contributes almost 40 % of South Africa's total greenhouse gas emissions. Improving the efficiency of the Lurgi gasifiers at the plants by around 10 –15 % could reduce coal consumption by 8 % and CO_2 emissions by 10 mt. No cost data was available on this option.

Extraction of coal-bed methane Some coalfields, particularly in the Waterberg area, have huge quantities of coal-bed methane (estimated at 2 trillion cubic feet). The CBM could be exploited and utilised for providing energy to rural industries, at the same time reducing the leakage of methane during mining.

Residential sector

In South Africa a distinction needs need to be made between those households that have access to grid electricity and those that do not, as there is a large difference in energy use between the two groups. In 1998 there were estimated to be around 2.76 m households with established grid connections, a further 3.18 m households that have been newly electrified and 3.47 m households without electrification.

Mitigation options

Mitigation options have been considered both for those houses with access to grid electricity and those without a grid-connection.

Replacing incandescent lights	CFLs use about 25 % of the electricity of incandescent lights and can be used to replace them in many applications. However, the less a light is used, the less economic it becomes to use a CFL, since the higher capital cost more than offsets the cost of electricity savings.
Efficient stoves	The overall efficiency of a typical wood or coal stove is around 35 %, but more efficient models are available with efficiencies of up to 50 % (representing a 30 % reduction in fuel use).
Hot plate to gas cooking	Fuel switching from electricity (generated from coal) to gas for cooking could significantly reduce CO_2 emissions.
Solar water heater	Stand-alone solar water heaters can be used to replace water heating using coal, wood, paraffin or LPG. Low cost models are now available that make this option more attractive than was previously the case.
Insulation of hot water cylinders	Extra insulation can be applied to hot water tanks and would typically save about 12 % of total electricity use.
Thermally efficient housing	Thermally efficient houses tailored to the needs of South Africa have been developed that can reduce fuel consumption by around 70 %. The house includes thermally efficient design components including window overhangs, insulated walls and ceiling, sealing and weather stripping.
Electricity to gas for space heating	CO_2 emissions from gas are around half those of electricity. These savings can be realised by using standalone heaters using bottled gas rather than electricity.
Solar home system	A solar home system consists of a 50 W_p solar panel, battery storage, a CFL and at least on electricity socket. Such systems can reduce CO_2 emissions in rural areas by replacing paraffin and gas with solar generated electricity for lighting, avoiding the need to recharge batteries from grid electricity and the need for a grid connection.
Paraffin to gas cooking	Gas cooking is more efficient than that using paraffin and will result in lower emissions of CO_2.

Commercial sector

Commercial sector energy use was around 60 PJ in 1998, with electricity use accounting for 95 %. Most energy is used is cooling and ventilation, followed by space heating, water heating and lighting.

Mitigation options
There is considerable scope for energy savings within the commercial buildings sector. New buildings generally use much less energy per square metre than the existing building stock and so most of the measures considered are aimed at narrowing this difference.

Efficient lighting	Lighting retrofits in commercial buildings include the replacement of standard fluorescent tubes with more efficient lighting and introducing lighting controls, such as occupancy sensors. Case studies have shown that these measures can save around 20 % to 40 % of electricity used in lighting.
VSD on fans	Variable speed drives in fans to use less electricity than conventional electric motors by automatically changing the speed of the motor in proportion to the air flow that is required.
Solar water heating	Solar water heating is a viable option in South Africa as long as a back up system is available for the when solar irradiation is insufficient (about 10 % of the time).

Transport
Energy use in road transport in 1996was 470 PJ and has been growing at around 3 % per year. The average age of vehicles on the road is higher than in Europe and most petrol engine cars still use leaded petrol and do not have three-way catalysts. Consequently, as well as producing CO_2 car use contributes to incidence of photochemical smog in major urban centres, such as Cape Town.

Mitigation options

Transport management	Transport management improvements refer to both freight and passenger transport (buses). Cost effective measures are likely to includes packages such as driver performance training, improved engine technologies, improved logistics and fuel monitoring and reporting schemes.
Demand management	Demand management in urban centres to reduce car use could include improved public transport, lane markings for non-motorised transport such as bicycles, walkways for pedestrians, car sharing through lift-clubs

TECHNO-ECONOMIC SCREENING

The CO_2 mitigation options identified in the previous section have been ranked by their cost of abatement to generate an emission reduction cost-curve for South Africa as shown in Figure A3.2. The major options are also summarised in Table A3.2.

This shows that a number of the mitigation opportunities identified in the different sectors are cost-effective (i.e. their net cost is negative). These include improved maintenance of freight vehicles and improved driver training, compact fluorescent lightbulbs in the domestic sector, variable speed drives on fans for commercial space heating and cooling, lighting retrofits in commercial buildings and more efficient cooking stoves in traditional dwellings.

Other options that are slightly more expensive include renovating existing coal plant in the electricity industry, switching to gas for cooking, co-generation in industry and using gas instead of paraffin for cooking.

Other options that have been identified include boiler improvements in industry, solar water heating in both the domestic and commercial sectors, thermally efficient housing and solar home systems.

Figure A3.2 CO_2 cost-abatement curve for South Africa

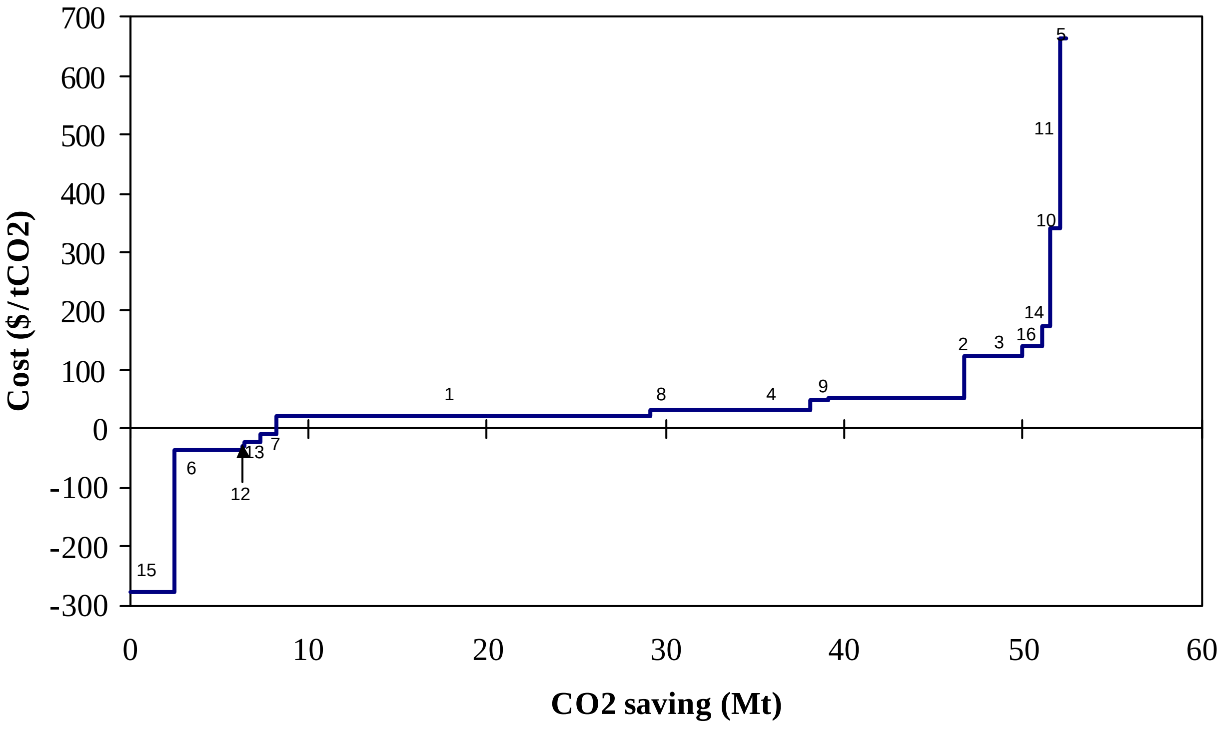


Table A3.2 Summary of the CO_2 savings and cost of abatement for South Africa

Key	Option	CO_2 saving $MtCO_2$	Cost of abatement ($/tCO2)
	Power		
1	Retrofitting CFBC	20.85	21
2	Wind	0.93	122
3	Biomass	2.32	124
	Industry		
4	Co-generation	8.96	32
5	Boiler improvements	0.29	664
	Domestic		
6	Compact fluorescent lightbulbs	2.88	-38
7	Efficient stoves	0.87	-9
8	Gas stoves	0.03	31
9	Solar water heaters	1.03	50
10	Thermally efficient housing	0.57	340
11	Solar home	0.03	538
	Commercial		
12	VSD on fans	0.12	-30
13	Lighting retrofit	0.90	-21
14	Solar water heating	0.44	173
	Transport		
15	Improved maintenance and driver training	2.56	-250 to -300
16	Improved traffic flow	1.14	142

ENVIRONMENTAL, SOCIAL AND DEVELOPMENT SCREENING

Following the economic analysis, some of the options that offer the largest greenhouse gas reduction opportunities in each sector or those that could have large social and development benefits have been selected for further screening against a range of sustainability criteria.

Power generation

Mitigation options have been assessed relative to a pulverised coal baseline.

Retrofitting CFBC technology Retrofitting CFBC technology will reduce emissions of sulphur oxides, as much of the sulphur is absorbed in the limestone bed. This should improve air quality around Witbank and Mpumalanga Province where most of the coal-fired plants are located and reduce transboundary air pollution in Swaziland and Mozambique. Water acidification in the locality should also be reduced.

Wind The use of wind turbines to generate energy will reduce non-greenhouse gas air pollutants so improving air quality. Wind energy does not generate any waste unlike the use of coal. The use of wind turbines for rural electrification may assist in the growth of rural commercial and industrial facilities. These would create employment and contribute to rural development and the reduction of poverty.

Biomass The use of biomass for electricity generation would reduce emissions of sulphur oxides compared to a coal plant. The planting and harvesting of biomass could provide additional employment to local communities, as it is relatively labour intensive. This provision of jobs could help with rural development and help to reduce poverty.

Table A3.3 Summary of sustainability impacts of potential CDM options in the power sector

	Retrofit CFBC	Wind	Biomass
Environmental impacts			
Air quality	+	+	+
Water quality	+	+	0
Flood prevention	0	0	0
Soil conservation	0	0	+
Solid waste	+	+	0
Noise	0	0	0
Biodiversity protection	0	0	0
Social and development benefits			
Employment	0	+	+
Rural development	0	+	+
Poverty reduction	0	+	+
Benefits to key groups	0	0	0

Industry

A summary of the sustainability impacts of the industrial mitigation measures that have been identified is shown below.

Cogeneration	Emissions of non-greenhouse gas emissions will be reduced
Improved industrial boilers	Emissions of non-greenhouse gases will be reduced, Particular SO_2, as a substantial proportion of the sulphur is retained in the fluidised bed.

Table A3.4 Summary of sustainability impacts of potential CDM options in the industrial sector

	Cogeneration	Improved boiler efficiency
Environmental impacts		
Air quality	+	+
Water quality	0	0
Flood prevention	0	0
Soil conservation	0	0
Solid waste	+	+
Noise	0	0
Biodiversity protection	0	0
Social and development benefits		
Employment	0	0
Rural development	0	0
Poverty reduction	0	0
Benefits to key groups	0	0

Residential sector

The following section highlights the major sustainability benefits of greenhouse gas mitigation measures aimed at both grid and non-grid connected households.

CFLs	CFLs use less electricity than conventional bulbs and therefore also reduce non-greenhouse gas emissions from electricity generation. Since they have a lower life-cycle cost than the incandescent lights, they can reduce expenditure on energy and may help reduce poverty.
Efficient stoves	Efficient stoves can reduce depletion of vegetation and so help prevent soil erosion and loss of habitat and biodivesity. Local air pollutants such as particulates can be reduced significantly. Many South African Townships, particularly those in Gauteng and Mpumalanga Provinces have high incidence of acute respiratory infection, arising out of poor air quality from the domestic combustion of D-grade coal. These coals have a high ash content and so better utilisation of coal can also help to reduce ash residues. More efficient stoves

can reduce expenditure on energy and help reduce poverty. Using less fuel can reduce the time taken to fetch fuel, a task usually undertaken by women.

Paraffin to gas cooking Using gas rather than paraffin for cooking in non-grid connected households can reduce non-greenhouse gas emissions and reduce the incidence of paraffin poisoning.

Solar water heater Solar water heaters will provide low-income households with more hot water than they would be able to boil on a stove or a fire. They can also improve local air quality by reducing air pollutants such as particulates. Local manufacture of such heaters could create additional demand for labour.

Thermally efficient housing Thermally efficient houses will reduce the need for heating fuels and therefore reduce the associated non-greenhouse gas pollutants. Since some coal and biomass use will be displaced there will also be benefits in terms of reduced ash disposal and possibly biodiversity protection. There may also be a net positive effect on expenditure by low-income households, helping to reduce poverty. The construction of such homes should provide additional local labour for the incremental building requirements over a standard house.

Solar home system Solar homes will reduce the need for paraffin that carries the risk of poisoning and of candles which may cause fires in low-income households. They will also eliminate the need for batteries and the associated waste disposal problems. They will increase employment through the manufacture and installation of the solar system.

Table A3.5 Summary of sustainability impacts of potential CDM options in the residential sector

	CFLs	Efficient stoves	Paraffin to gas	Solar water heaters	Thermally efficient housing	Solar homes
Environmental impacts						
Air quality	+	+	+	+	+	+
Water quality	0	0	0	0	0	0
Flood prevention	0	0	0	0	0	0
Soil conservation	0	+	0	0	0	0
Solid waste	0	0	0	0	+	+
Noise	0	0	0	0	0	0
Biodiversity protection	0	+	0	0	+	0
Social and development benefits						
Employment	0	0	0	+	+	+
Rural development	0	0	0	0	0	+
Poverty reduction	+	+	0	+	+	+
Benefits to key groups	0	+	+	0	0	0

Commercial sector

The sustainability impacts of mitigation measures in the commercial sector are summarised below.

VSD on fans Variable speed drives will reduce electricity consumption, so reducing emissions of non-greenhouse gases. Currently, these motors would need to be imported and so there could be a negative impact on employment

Lighting retrofit Retrofitting a more efficient lighting system will reduce emissions of non-greenhouse gases.

Solar water heating Solar hot water heating will reduce emissions of non-greenhouse gases.

Table A3.6 Summary of sustainability impacts of potential CDM options in the commercial sector

	VSD on fans	Efficient lighting	Solar water heating
Environmental impacts			
Air quality	+	+	+
Water quality	0	0	0
Flood prevention	0	0	0
Soil conservation	0	0	0
Solid waste	0	0	0
Noise	0	0	0
Biodiversity protection	0	0	0
Social and development benefits			
Employment	-	0	0
Rural development	0	0	0
Poverty reduction	0	0	0
Benefits to key groups	0	0	0

Transport

The major sustainability benefits of measures identified in the transport sector are as follows.

Improved maintenance of freight vehicles Improving the servicing of freight vehicles will help maintain optimum engine efficiency and so help reduce emissions of non-greenhouse gases such as nitrous oxides, volatile organic compounds and particulates. If additional mechanics are needed then this will clearly have a positive impact on employment.

Demand management Introducing travel demand management, such as new bus lanes will improve traffic flow and so help minimise fuel use. A reliable service could benefit key groups, such as the poorer sections on society who rely on public transport.

Table A3.7 Summary of sustainability impacts of potential CDM options in the transport sector

	Improved maintenance of freight vehicles	**Transport demand management**
Environmental impacts		
Air quality	+	+
Water quality	0	0
Flood prevention	0	0
Soil conservation	0	0
Solid waste	0	0
Noise	0	0
Biodiversity protection	0	0
Social and development benefits		
Employment	+	0
Rural development	0	0
Poverty reduction	0	0
Benefits to key groups	0	+

PRIORITISATION OF CDM OPPORTUNITIES IN SOUTH AFRICA

The following table summarises the key CDM opportunities in South Africa, scoring them on the cost of mitigation, their potential for reducing emissions and their contribution to sustainable development, based on their other environmental and social and development benefits.

Table A3.8 Summary of possible CDM opportunities identified in South Africa

Opportunity	Mitigation cost	Greenhouse gas reduction potential	Other environmental benefits	Social and development benefits
Power				
Retrofitting CFBC	**	**	***	*
Wind	*	*	***	***
Biomass	*	*	**	***
Industry				
Co-generation	*	**	**	*
Boiler improvements	*	*	**	*
Domestic				
Compact fluorescent lightbulbs	***	*	*	*
Efficient stoves	***	*	***	**
Gas stoves	*	*	*	*
Solar water heaters	*	*	*	**
Thermally efficient housing	*	*	*	**
Solar home	*	*	**	***
Commercial				
VSD on fans	***	*	*	*
Lighting retrofit	***	*	*	*
Solar water heating	*	*	*	*
Transport				
Driver training & better maintenance	***	*	*	*
Improved traffic flow	*	*	*	*

As industry, has not been considered in detail, the scope for CO_2 reduction that has been identified is less than for China and India. Nevertheless, cost effective opportunities exist in many areas including the domestic, commercial and transport sectors.

- In the domestic sector both the use of compact fluorescent lights (for grid connected households) and efficient stoves (targeted at non-grid connected households) are financially attractive, with the latter also having strong sustainability benefits.

- In the commercial buildings sector, the use of controllers on air conditioning fans and improved lighting systems are both shown to be cost-effective, although their contribution to sustainable development is not as strong as some of the domestic sector options.
- In commercial transport, improved driver training and better vehicle maintenance has been identified as highly cost effective.
- In the power sector, the most financially attractive option is to retrofit circulating fluidised bed combustion to the existing coal fired power stations, while in terms of sustainability both wind and biomass for electricity generation have strong co-benefits.
- Many of these options are in line with the goals of the 1998 Energy White Paper to increase access to affordable energy services, stimulate economic development, manage energy-related environmental impacts and achieve secure energy supply through diversity

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