Understanding the Clean Development Mechanism and its dual aims – The case of China’s projects

Qie Sun
Doctoral Thesis

Industrial Ecology
School of Industrial Engineering and Management
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Understanding the Clean Development Mechanism and its dual aims
– The case of China’s projects

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Contact Information

Qie Sun
Industrial Ecology
School of Industrial Engineering and Management
Royal Institute of Technology (KTH)
SE-100 44 Stockholm, Sweden
Phone: +46 8 790 6744
Fax: +46 8 790 5034

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锲而舍之，朽木不折
锲而不舍，金石可镂
——《荀子·劝学》
I started my PhD studies at Industrial Ecology, KTH, five years ago, when I became one of the first 58 students financed by a scholarship from the China Scholar Council (CSC) in 2006. The CSC provided me financial support for the first three years, which is gratefully acknowledged.

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It’s really great having all of you in my life!
Abstract

Having been running for over 10 years, the Clean Development Mechanism (CDM) is considered an innovative and successful mitigation initiative. CDM has the dual aims of helping industrialised countries achieve compliance with their emission limitation and reduction commitments in a cost-effective way, while simultaneously assisting developing countries in sustainable development. This thesis does a comprehensive analysis of the dual aims of CDM and is intended to assist in discussions about the post-2012 regime regarding CDM.

To analyse the aim of assisting mitigation in a cost-effective way, the prices of certified emission reductions (CERs) on the international carbon market was studied and the provision of CDM was tested by comparing the amount of CERs with the mitigation commitments of the Annex I countries. It was found that CDM plays an important role in maintaining the international carbon price at a low level and that the total amount of CERs alone had already reached up to 52.70% of the entire mitigation commitments of industrialized countries by the end of 2010 and was continuing to grow before 2012.

A theoretical analysis of the impacts of CDM showed that CDM has a double mitigation effect in both developing countries and industrialised countries, without double counting at present. A quantitative evaluation of the effects of China’s CDM projects on China’s total emissions showed that the contribution of CDM projects to limiting total emissions is small due to the dominance of fossil fuels, but CDM’s role in stimulating renewable energy is significant, e.g. about 11% of hydropower and 93% of wind power was generated by CDM projects in 2010. The results provide strong evidence in support of CDM’s contribution under the current Kyoto Protocol mitigation regime.

To analyse the aim of promoting sustainable development in developing countries, popular methods such as checklist, Multi-Criteria Analysis (MCA) and Cost-Benefit Analysis (CBA) were reviewed, a CBA of co-benefits of China’s CDM projects was carried out, and the Analytic Hierarchy Process (AHP) method was applied in an experimental study. The results showed that every method has its own advantages and problems. In other words, neither the CBA of co-benefits nor the AHP method alone is able to assess sustainable development in a completely satisfactory way. Currently, a bottom-up approach through engaging local stakeholders in CDM design and approval, combining a mandatory monitoring and evaluation of co-benefits, could be more effective for safeguarding local sustainable development than any consolidated standards.

The future of the CDM is still unclear mainly due to uncertainties about the post-2012 regime. This thesis shows that there is more than sufficient reason for CDM to continue after 2012. Industrialised countries in general should make more substantial efforts to reduce their domestic emissions rather than blaming developing countries. For developing countries, learning from the CDM projects and further applying the knowledge, technology and experiences to their domestic development agenda could be more valuable than the present CER revenues. CDM can be an important starting point for developing countries to gradually make incremental greenhouse gas (GHG) reduction and limitation efforts.
Key words

Clean development mechanism (CDM), Climate change mitigation, Kyoto Protocol, Sustainable Development, China’s mitigation strategy, Cost benefit analysis (CBA), co-benefits, Multi-criteria analysis (MCA), Analytic Hierarchy Process (AHP)
# Glossary

<table>
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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>AHP</td>
<td>Analytic Hierarchy Process</td>
</tr>
<tr>
<td>BAU</td>
<td>Business-as-usual</td>
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<tr>
<td>CBA</td>
<td>Cost Benefit Analysis</td>
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<td>CDM</td>
<td>Clean Development Mechanism</td>
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<tr>
<td>CER</td>
<td>Certified Emission Reduction</td>
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<td>COP</td>
<td>Conference of Parties</td>
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<td>CO₂e</td>
<td>CO₂ Equivalence</td>
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<tr>
<td>DNA</td>
<td>Designated National Authority</td>
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<tr>
<td>DoE</td>
<td>Designated Operational Entity</td>
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<tr>
<td>EB</td>
<td>Executive Board</td>
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<tr>
<td>ETS</td>
<td>Emission Trading Scheme</td>
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<tr>
<td>EU ETS</td>
<td>European Union Emission Trading Scheme</td>
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<td>FAR</td>
<td>Fourth Assessment Report (of the IPCC)</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>JI</td>
<td>Joint Implementation</td>
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<tr>
<td>LULUCF</td>
<td>Land Use, Land-Use Change and Forestry</td>
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<tr>
<td>MCA</td>
<td>Multi-Criteria Analysis</td>
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<tr>
<td>NBSC</td>
<td>National Bureau of Statistics of China</td>
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<tr>
<td>NDRC</td>
<td>National Development and Reform Commission (of China)</td>
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<tr>
<td>NGOs</td>
<td>Non-Governmental Organizations</td>
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<tr>
<td>pCDM</td>
<td>Programmatic CDM or policy CDM</td>
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<tr>
<td>PDD</td>
<td>Project Design Document</td>
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<tr>
<td>PM</td>
<td>Particle Matters</td>
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<tr>
<td>ppm</td>
<td>Parts per million</td>
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<tr>
<td>SCE</td>
<td>Standard Coal Equivalent</td>
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<tr>
<td>TAR</td>
<td>Third Assessment Report (of the IPCC)</td>
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<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
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1 Introduction

1.1 Clean Development Mechanism and its dual aims

The last two decades witnessed an worldwide progression to the unprecedented anthropogenic environmental problem of climate change and its likely devastating impacts (Houghton, 2001; Kerr, 2007). There is widespread consensus that mitigation is necessary to avoid long-term irreversible climate change and its consequences (IPCC, 2001; 2007). The greatest effort is undoubtedly the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), which defines the only legal binding structure existing in the world at present (Grubb, 2010). The Kyoto Protocol not only stipulates quantified emission limitation and reduction commitments for the industrialised countries in Annex I (so-called Annex I countries), but also suggests the principle of 'common but differentiated responsibilities', which serves as the core and bedrock of international cooperation on climate change.

To help Annex I countries fulfil their commitments in a cost-effective way, three flexible mechanisms were introduced, namely Joint Implementation (JI), Emission Trading Scheme (ETS) and Clean Development Mechanism (CDM). Within the three mechanisms, CDM is the only one involving not only industrialised countries but also the developing world. CDM allows emission reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO$_2$ equivalents (CO$_2$e). These CERs can be traded and sold, and used by industrialised countries to meet part of their emission reduction targets under the Kyoto Protocol (UNFCCC, 1998). In other words, CDM is defined with dual aims, i.e. to help industrialised countries to achieve compliance with their emission limitation and reduction commitments in a cost-effective way, while simultaneously assisting developing countries in sustainable development.

Under the clean development mechanism:

(a) Parties not included in Annex I will benefit from project activities resulting in certified emission reduction; and

(b) Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, ...

(UNFCCC, 1998)

CDM represents an innovative, multi-level market-based policy instrument and is considered one of the most successful mitigation efforts by far (Figueres and Streck, 2009). Although defined in Article 12 of the Kyoto Protocol, CDM was nothing more than an innovative concept before 2001 (Lecocq and Ambrosi, 2007). The major operational guidelines for CDM were agreed upon at the 7th Conference of Parties (COP7) in Marrakech in 2001, and the executive board (EB) of CDM was founded and started to work immediately afterwards. It took another two years to reach agreement on the rules for Land Use, Land-Use Change and Forestry (LULUCF) projects. The first CDM registration request was submitted to the UNFCCC on 1 December 2003, and there were only four applications submitted in 2003 (Fenhann, 2011; Fenhann and Staun, 2010). CDM projects started to boom when the required number of countries finally ratified the Kyoto
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Protocol in 2005. By the end of 2010, 5670 candidate projects had been proposed in the CDM pipeline, representing in total over 2.7 billion tonnes of CERs by the end of 2012, and 2711 of these candidates had been registered, annually delivering more than 400 million tonnes of CERs (UNFCCC, 2011b).

Despite these great achievements, controversy over CDM and especially over its dual aims has never stopped since the Kyoto Protocol first came into force. Previous studies have separately examined the dual aims from a number of aspects, but there has been no thorough analysis of CDM simultaneously considering the dual aims, becomes particularly significant as the Kyoto Protocol's first commitment period at the end of 2012 is approaching, while a post-2012 regime has still not been decided yet (Figueres and Streck, 2009). This thesis examined CDM in detail, especially focusing on important questions relating to the dual aims, but also including other issues relating to CDM.

Regarding the aim of achieving mitigation commitment in a cost-effective way, previous studies often focused on the so-called additionality of CDM activities, which indicates that a project activity would not occur in the absence of CDM (UNFCCC, 2002). The additionality has been discussed from different angles, including its measurability, leakage and permanence (Paulsson, 2009). However, there have been no studies systematically analysing: (1) whether the price of CERs represents a cost-effective option for industrialised countries to achieve their mitigation commitments, (2) how much the CDM could contribute to the total reduction commitments under the Kyoto Protocol, and (3) how CDM will affect the domestic emissions of developing countries.

In contrast, a larger number of studies have been devoted to the debate on whether CDM assists developing countries in sustainable development (Dechezleprêtre et al., 2009; Kolshus et al., 2001; Sutter and Parreño, 2007). A project design document (PDD) submitted to the UNFCCC for registration has to demonstrate the project’s additionality following relevant baseline and monitoring methodologies (UNFCCC, 2002). However, developing countries do not have strong incentives to erect a barrier to CDM projects in terms of sustainable development (Sutter, 2003). Regarding this, a number of initiatives have been launched in order to feature registered CDM projects and promote sustainable development at local level, e.g. the Gold Standard and the Community Development Carbon Fund (The Gold Standard Foundation, 2009; The World Bank, 2011). Unfortunately, projects labelled by these initiatives do not drastically outperform non-labelled projects (Nussbaum, 2009). Nevertheless, an effective method to examine the performance of CDM in terms of sustainable development is always interesting to researchers, although there will probably never be an uncontroversial approach applicable to all CDM projects regardless of project categories and locations, given significant differences in context-specific situations and policy priorities in different countries (Disch, 2010; Huang and Barker, 2008; Hugé et al., 2009; Nussbaum, 2009).

1.2 China’s CDM projects and CO₂ emissions
The analysis and discussion in this thesis centre primarily on China’s CDM projects because:

- China currently dominates the world’s CDM projects
China has experienced a surge in greenhouse gas (GHG) emissions in recent years (Schneider, 2009; Schroeder, 2009a; b)

China is a key country in the international climate change regime (Heggelund, 2007).

China’s first CDM project was registered on 26 June 2005, and only a total of three projects had been registered by the end of 2005. Despite this slow start, the number of CDM projects in China increased dramatically thereafter. By the end of 2010, a total of 1148 projects in China had been registered by the UNFCCC, accounting for 42% of total registered CDM projects worldwide, and these projects are estimated to deliver 261.4 million tonnes of CERs annually, representing 62% of the global total (UNFCCC, 2011b). Therefore, it is very important to study China’s CDM projects, as the country has led the global CDM market on the supply side since 2006 (Capoor and Ambrosi, 2006).

Following the principle of common but differentiated responsibilities, developing countries do not need to undertake any limitation or reduction commitment in the Kyoto Protocol’s first commitment period before 2012. A major way for them to participate in international climate change mitigation is by providing cheap reduction credits for the Annex I countries. Despite its dominance of CER supply, China’s GHG emissions surge has become the target of accusations in recent international negotiations on climate change (Heggelund, 2007). A number of studies show that China is currently the largest emitter of CO₂ in the world, although the amount of China’s historical cumulative emissions still remain very low, especially on the per capita level (Gregg et al., 2008; Guan et al., 2009; Oberheitmann, 2010; The Netherlands Environmental Assessment Agency, 2007). In response to both international and domestic pressure and in an attempt to present a responsible image in international affairs, China’s national government announced a national strategic CO₂ mitigation target to unconditionally reduce domestic CO₂ intensity of GDP by 40-45% by 2020 compared with the 2005 level (hereafter referred to as the China’s domestic mitigation target, for more discussion about the target see Paper IV). Thus, it is interesting to investigate the relationship between China’s provision of CERs and its domestic CO₂ intensity progress.

In addition, the importance of developing countries participating in climate change mitigation has already been recognised (Dubash and Rajamani, 2010; Figueres and Streck, 2009). As the world’s largest developing country and its influence in the G77 of Third World states and the United Nations, China is playing a prominent role in the present climate regime, and this fact will not change in post-2012 negotiations (Grubb, 2010; Heggelund, 2007). Therefore, better understanding of China’s attitudes toward international cooperation regarding climate change will greatly help to solve the Copenhagen’s blame game and direct the process to a more constructive phase (Grubb, 2010).

1.3 Aims and objectives

The main aim of the thesis was to comprehensively study CDM, especially its dual aims, and the analysis concentrated on China’s CDM projects. Specific objectives included in the thesis were to:

- Analyse CDM as a type of innovative instrument for achieving climate change mitigation;
- Study the effects of China’s CDM projects on fulfilling the commitments of Annex I countries;
• Study the impacts of CDM projects on China’s mitigation target;
• Discuss different methods used to assess the impacts of CDM projects on sustainable development, namely
  o assess co-benefits of China’s CDM projects and examine the policy implications of co-benefit assessments regarding sustainable development; and
  o compare CDM projects in terms of sustainability using the analytic hierarchy process (AHP) method; and
• Discuss other issues relating to CDM and its future.

1.4 Methodology

CDM and its Dual Aims - the case of China’s projects

Aims

- CDM as a type of innovative instrument for achieving climate change mitigation
- The effects of China’s CDM projects on fulfilling the Annex I countries’ commitments
- The effects of CDM projects on achieving China’s mitigation target
- The impacts of CDM projects on sustainable development
- Other concerns about the CDM

Objectives

- Cost-effectiveness of CDM
- The provision of China’s CDM projects
- China’s mitigation target in 2010-2020
- A conceptual analysis of CDM’s effects on the Annex I countries and developing countries
- CDM’s mitigation effects in China
- A review of popular methods
- CBA of the co-benefits of China’s CDM projects
- An experimental study using AHP
- Other concerns about CDM
- Looking ahead

Approach

- From an emission trading perspective
- From a governance perspective

Figure 1-1 The overall methodology adopted in the thesis

The overall methodology adopted is shown in Figure 1-1. The approaches used to achieve the five specific objectives are described in the following section.
• Analysing of CDM as a type of innovative instrument for achieving climate change mitigation

To achieve this objective, the principles and innovative features of CDM were discussed in a section, which serves as the theoretical pillar of the whole study. Concretely, the discussion was based on environmental economics, from an emissions trading perspective and a governance perspective, respectively. From the emissions trading perspective, the traditional concept and empirical exercises of emissions trading were reviewed and then compared with the principles of CDM in order to investigate the innovative features of CDM. From the governance perspective, the governance of CDM was considered for practical exercises in co-management, which is the most discussed form of institution for addressing the multi-level challenges of commons.

• Studying the effects of China’s CDM projects on fulfilling the commitments of Annex I countries

To achieve this objective, the cost-effectiveness of CDM was analysed and the provision of China’s CDM projects was tested in separate studies. To study the cost-effectiveness, the average prices for CERs were compared with the costs for the Annex I countries to meet their mitigation compliances, referring to marginal costs, average costs and contemporary market prices. To test the provision, the amount of CERs from China’s CDM projects was compared with the mitigation commitments of Annex I countries under the Kyoto Protocol. This study concentrated on the 19 industrialised countries involved in China’s CDM project activities.

• Studying the impacts of CDM projects on China’s mitigation target

To achieve this objective, two scenarios were first developed to forecast China’s CO₂ emissions in 2010-2020, referring to annual GDP growth of 8% and 10% respectively, assuming that China’s mitigation target, namely to reduce domestic CO₂ emissions per unit GDP by 40% by 2020 compared with the 2005 level, will be achieved. Next, a conceptual analysis was performed to discuss CDM’s mitigation effects on industrialised countries and developing countries. On this basis, CDM’s impacts on China’s emissions in 2005-2012 were estimated by comparison of China’s CDM reductions and the CO₂ emissions in the absence of CDM.

• Examining the impacts of CDM projects on sustainable development

This thesis was address from a methodological perspective, i.e. focusing on how sustainability is analysed using different methods in terms of CDM projects. Concretely, a review of popular methods, e.g. Cost-Benefit Analysis (CBA) and Multi-Criteria Analysis (MCA), with respect to the sustainability of CDM projects was made. Next, the co-impacts of China’s CDM projects were evaluated using the CBA method. The co-impacts considered in this study were the reduction in air pollutants, namely SO₂, particulate matter (PM) and NOₓ, and related avoided deaths and crop losses. The policy implications of co-impacts were also examined. Then, an experimental study using the AHP method was carried out to compare a hydropower project with a HFC23 decomposition project regarding sustainable development. Pros and cons of the AHP method in terms of sustainable development assessment of CDM projects were examined.

• Discussing other issues relating to the CDM and its future
To provide a comprehensive scope to the study, some other issues relating to CDM and its dual aims were also examined, e.g. distribution of CDM projects, transaction costs and the problem of ‘running to the bottom’ and ‘low-hanging fruit’. The findings were involved in the discussion about the future of CDM and to draw conclusions.

1.5 Brief introduction to Paper I-V

This thesis is based on five published papers, which are presented briefly below.

Paper I


Paper I discusses the governance of Climate Change Mitigation, which serves as the theoretical basis of this thesis. The study found that a working institution should be able to address the cross-scale and multi-level challenges in the governance of Climate Change Mitigation. Currently, the two most studied forms of institution are co-management and transnational networks, of which a common point is that they both attempt to build up cooperative networks. Paper I also discusses how to improve cooperative networks as a working institution. Regarding CDM, Paper I concluded that CDM could be considered practical exercises in co-management.

Paper II


Paper II studied the co-benefits of China’s CDM projects and discussed their policy implications. Through co-benefits assessment of Chinese CDM projects, the study found that many energy-related climate change mitigation activities, including CDM projects, are able to produce a significant amount of co-benefits. While these should not be involved in current international CCM negotiations or used to ensure projects’ contribution to sustainable development, co-benefits analysis can indicate synergies or optimised trade-offs between CCM and protecting local environments, which is valuable for decision-making in developing countries, especially for local governments. Paper II contributed to the discussion on the impacts of CDM projects on sustainable development.

Paper III


Paper III provides an analysis of China’s policy instruments for energy conservation and climate change before 2010. In that stage, China’s mitigation target was based on a decrease in energy consumption per unit GDP, rather than a reduction in carbon dioxide levels. The study showed that China’s national energy consumption per unit GDP had been declining since 2005, indicating that the policy instruments for energy conservation and climate change were in general effective and important. Regarding categories of policy instruments, the regulations on
technological improvement made the greatest contribution in terms of reducing energy consumption per unit economic output.

**Paper IV**


Paper IV was a direct response to China’s first straightforward mitigation target, i.e. to reduce domestic CO\textsubscript{2} emissions per unit GDP by 40-45% by 2020 compared with the 2005 level. Several growth scenarios were constructed to project China’s future emissions, where China’s future population and economic growth were two main variables. China’s CO\textsubscript{2} emissions in 2010-2020 were compared with the amount estimated in the business-as-usual scenarios with different rates of economic growth. Paper IV added to the discussion about the impacts of CDM on China’s domestic emissions. The same method was used in Section IV of this thesis to forecast China’s future CO\textsubscript{2} emissions and the data were updated.

**Paper V**


Paper V compared two CDM projects in terms of their impacts on sustainable development, using the popular AHP method in an experimental study. Two groups of post-graduate students performed the assessment and both found that the HFC23 decomposition project studied was a greater contributor to sustainable development than the hydropower project, although the details differed. The outcome could have been different if the assessment had been performed by real stakeholders and decision-makers instead of students. Nevertheless, the study confirmed that AHP can be a useful method for decision-making, especially in a complex situation relating to sustainable development, although beset with some weaknesses. Paper V contributed to the discussion about CDM’s impacts on sustainable development. Together with Paper II, it analysed different methods used to evaluate CDM projects regarding sustainability.

### 1.6 Structure of the thesis

The remainder of the thesis consists of five chapters, which are organised as follows:

- **Chapter 2: CDM as a type of innovative instrument for achieving climate change mitigation**

  The basics of CDM are introduced, followed by a theoretical discussion regarding the principle and innovative features of CDM.

- **Chapter 3: China’s CDM projects and CERs for Annex I countries**

  China’s CDM projects by the end of 2010 are reviewed and the cost-effectiveness and provision of CDM are studied.
• Chapter 4: CDM projects and China’s mitigation strategy

China’s mitigation targets for 2010-2020 are quantified and a conceptual analysis of CDM’s mitigation effects in Annex I countries and in developing countries is performed. The effects of CDM projects in China are then estimated.

• Chapter 5: CDM projects and sustainable development

A reviewed of existing studies on CDM project activities regarding sustainable development is followed by a CBA of the co-benefits of China’s CDM projects, and an experimental study using the AHP method.

• Chapter 6: Discussions and conclusions

The results from preceding chapters are summarised as background to a discussion about other issues relating to CDM. Finally, some thoughts about the future of CDM are presented.
2 CDM as a type of innovative instrument for achieving climate change mitigation

This chapter begins by introducing the basics of CDM, namely the working flow of a CDM project, baseline and monitoring methodologies and the concept of additionality. The theoretical underpinnings of the CDM and its innovative features are then described and discussed from an emissions trading perspective and from a commons perspective.

2.1 Basics of CDM

CDM allows the Annex I countries to use the CERs generated from emission reduction (or emission removal) projects in developing countries to meet part of their reduction commitments under the Kyoto Protocol. Generally, the working flow of a CDM project can be visualised as shown in Figure 2-1 (revised from Paper I), where two partners participate, i.e. a project owner from a developing country and a buyer of CERs from an industrialised country. In order to be registered as CDM, the project must first be approved by the designated national authority (DNA) of the host country, validated by a designated operational entity (DoE), and then approved by the CDM EB. Note that a CDM project may be developed without a buyer, while a letter of approval allowing the buyer’s participation is also needed when the buyer is available (Figure 2-1). After the project is registered, the practical amount of GHG reduction is monitored by the project owner (or other parties if needed) within a crediting period. The monitoring report has to be verified by another DoE, and the verified CERs can then be credited to the industrialised country’s account.

![Figure 2-1 The working flow of CDM](http://cdm.unfccc.int/CommonImages/ProjectCycleSlide.png)

In order to have the CERs accredited, any CDM project must qualify through a rigorous public registration process as shown above, where its additionality is demonstrated. The additionality, indicating that the project activity would not have occurred in the absence of CDM, is calculated by comparing the project activity with its relevant baseline methodologies on the basis of real, measurable and verifiable reductions (Hepburn, 2007). The calculation logic is based on measurement of individual mitigation activities, rather than a cap and trade system such as EU ETS (Figueres and Streck, 2009). However, the calculation logic has been heavily criticized as not leading to real reductions in absolute terms and subsequently not sufficient to change the current emission trends in developing countries in the long run (Carr and Rosembuj, 2008; Liverman, 2009; Paulsson, 2009; Pearson, 2007; Wara, 2007). This issue is analysed in particular in Chapter 5.

Two types of ‘additionality’ can be found in existing literature, referred to as environmental additionality and financial additionality (Greiner and Michaelowa, 2003; Meyers, 1999; Shrestha and Timilsina, 2002). The difference in emissions between a project activity and the related baseline is referred to as environmental additionality, while financial additionality, also called investment additionality or economic additionality, is used to indicate whether the project would be viable without the CER revenues. The additionality principle entitles registered CDM projects to legitimacy, and in the meantime excludes those highly profitable projects that would have happened anyway (Figueres and Streck, 2009; Schneider, 2009). Thus, some studies have suggested that the determination of additionality in a methodology is an optimisation process, which should neither be too harsh to allow any financial benefits to be gained by candidate projects, nor too loose to prohibit profitable investments for which CER revenues are not additional at all (Greiner and Michaelowa, 2003; Streck and Lin, 2008).

By the end of 2010, a total of 194 methodologies in nine groups had been approved by the CDM EB (UNFCCC, 2011b). In order to accommodate the wide range of activities and locations covered by CDM and to optimise the definition of additionality for existing project categories, the CDM EB has been continuously improving existing methodologies and approving new methodologies. In addition, every methodology is developed following a conservative principle, which guarantees the reliability of CERs in PDDs. Given their availability and reliability, PDDs are the main data sources of most studies, as they are in this thesis.

### 2.2 CDM as an innovative instrument

Climate change is an unprecedented global environmental problem that requires governance from international cooperation to local contributions to address its cross-scale and multi-level challenges (an analysis of the theoretical characteristics of CDM can be found in Paper I). CDM was developed as an innovative instrument bridging the industrialised and developing countries and pursuing collaborative efforts on climate change mitigation (Friberg, 2009; Hepburn, 2007; Schroeder, 2009a). In the following, the theoretical underpinnings and innovations of CDM are described.

#### 2.2.1 From an emission trading perspective

Climate change is a pure externality of anthropogenic activities and mainly results from the industrialization process as an unintended loss in welfare to the whole world (IPCC, 2001). Early in the 1920s, Pigou (1920) pointed out that forcing people to pay for the pollution made by themselves would increase the overall social benefits, and later this principle is often referred to
as the ‘polluter-pays principle’ (Hepburn, 2007). The polluter-pays principle means that the polluter has to bear all the costs of preventing and controlling any pollution caused, without receiving assistance of any kind, e.g. grants, subsidies or tax allowances (OECD, 1992). According to environmental economics, this can be achieved by e.g. levying a tax on polluters to internalise environmental externalities, which is called ‘Pigouvian Tax’ (Carlton and Loury, 1980; Krutilla, 1991). Alternatively, institutional economists suggest that assigning property rights to pollution and allowing trade in emission rights could solve environment problems in an efficient way (Coase, 1960; Daly and Farley, 2003). Dales (1968) was the first to explicitly propose a ‘market in pollution rights’ as a policy instrument, and argued that tradable emission permits could have compelling advantages over taxes. There are two ways to allocate emission permits, namely the ‘auction-off’ and ‘grandfather’ methods (Woerdman et al., 2008). As the name suggests, polluters have to bid for their emission rights under an auction system, while they can receive emission rights free of charge based on their historical emissions under a grandfather system.

In the case of climate change mitigation, the emission limitation and reduction commitments according to the Kyoto Protocol were defined on the basis of the grandfather method, while the ‘common but differentiated’ principle was adapted from the so-called polluter-pays principle. The three market-based flexible mechanisms under the Kyoto Protocol, i.e. ET, JI and CDM, embody practical advocacy of tradable emission permits to pursue cost-effectiveness. However, as mentioned above, the theoretical underpinnings of the three mechanisms are not a theoretical innovation, and the application of tradable permits is not completely new either. In the early 1990s, the United States established a domestic emission trading programme to cut down SO$_2$ emissions, and it was later viewed by many as a success (Hepburn, 2007; Woerdman et al., 2008). The current European Union Emission Trading Scheme (EU ETS), which started in 2005, copied most of its features from the US SO$_2$ trading programme (Christiansen and Wettestad, 2003).

CDM allows the reduction credits from climate change mitigation projects in developing countries to be used by the Annex I countries to meet part of their own reduction compliance under the Kyoto Protocol. This is an innovative instrument to achieve climate change mitigation (Foot, 2004; Friberg, 2009; Hepburn, 2007; Schroeder, 2009a). Compared with the traditional concept of emission trading, the novel features of CDM include the following aspects:

- **CDM enlarges the scope of participants** by involving developing countries in the mechanism, and is thus able to generate collaborative efforts on climate change mitigation. In a conventional emissions trading system, emission permits are allocated and transacted between ‘polluters’ who undertake the reduction responsibility, while those who do not cause pollution do not participate (Runge, 1995).

- **CDM is different from a traditional ‘cap and trade’ scheme**, such as the US SO$_2$ trading programme and the EU ETS. There is no cap on the total emissions of CDM projects, since developing countries do not undertake any compulsory reduction or limitation responsibilities under the Kyoto Protocol regime. In contrast, the calculation of CERs is based on an individual evaluation of project activities and relating baseline. This assessment logic is sometimes criticised as being the reason for emission leakage (Liverman, 2009; Pearson, 2007; Wara, 2007). However, Kallbekken (2007) showed that
CDM can significantly reduce carbon leakage irrespective of the methodology adopted. This issue is returned to in Chapter 4.

- CDM by design encourages a ‘win-win’ situation between industrialised and developing countries. In a conventional emissions trading system, polluters pay for no more than what they polluted and the compensation aims to prevent welfare from becoming ‘worse-off’. Under CDM, developed countries could obtain pollution permits at a cheap price; and developing countries do not only obtain CER revenues as ‘compensation’, but also have the possibility to better-off by making use of all direct and indirect benefits associated with the CDM (to be discussed in Chapter 5). Given the large amount of investment in renewable energy, developing countries are expected to avoid the emission-intensive route of development that most industrialised countries went through. In addition, technology transfer, capacity building and awareness promotion from CDM projects may be more valuable for developing countries to pursue extensive sustainable development.

### 2.2.2 From a governance perspective

Since the seminal paper ‘The Tragedy of the Commons’ (Hardin, 1968), studies have been using the ‘commons’ perspective to look at a variety of resources and environmental problems, including climate change (Agrawal, 2002; Dietz et al., 2003; Ostrom, 1990; Ostrom et al., 1999; Stern et al., 2002a). Existing theoretical studies and empirical evidence have shown that many common property resource (or commons for short) systems have proven capable of enduring and developing under an effective governance institution (Agrawal, 2002; Dietz et al., 2003; Ostrom, 1990; Ostrom et al., 1999; Stern et al., 2002b). However, such success has not been universally achieved in dealing with large-scale environmental problems, e.g. the climate change mitigation has frequently been identified as a ‘problem of tragedy’ (Kennedy, 2003; Milinski et al., 2006; Stern et al., 2002b).

Governance of commons usually resorts to studies on developing and implementing institutions. For large-scale commons such as the ambient climate, the focus of institutional design is on how to address the cross-scale and multi-level challenges (Agrawal, 2002; Betsill and Bulkeley, 2007; Dietz et al., 2002; Ostrom, 1990; Paavola, 2008). Berkes (2008) suggests that this could be done at various levels of institution that interact horizontally (across the same level) and vertically (across various levels). Within a diversity of forms of institution, the interests of existing studies mainly fall into two categories: co-management (or cross-level interplay), which intends to incorporate different actors vertically across various administrative levels (Adger et al., 2005; Berkes, 2006; Carlsson and Berkes, 2005; Carlsson and Sandström, 2008; Young, 2006), and transnational networks, in which local actions horizontally across national boundaries are the central focus (Betsill and Bulkeley, 2004; 2006).

Co-management is one of the most discussed forms of institution to date for addressing the multi-level challenges of commons (see Paper I). The idea of co-management is to overcome the weakness of the traditional ‘top-down’ system of resource management and is founded on the basis of power- and responsibility-sharing between governments and local communities (Berkes, 2006; Carlsson and Sandström, 2008; Cash et al., 2006; The World Bank, 1999). Given that the administrative scale of governance encompasses international, national, municipal, local community and private level, co-management aims to change the traditional top-down system...
into a flat social network and re-configure the power and responsibility among stakeholders, as shown in Figure 2-2 (Carlsson and Sandström, 2008; Cash et al., 2006; The World Bank, 1999). For further discussion about co-management, see Paper I.

![Figure 2-2 Levels of stakeholders and co-management](http://www.worldbank.org/wbi/conatrem/)

From a governance perspective, the governance of CDM can be regarded as practical exercises in co-management. As illustrated in Figure 2-1, participants in a CDM project include international organisations, national authorities, a project owner, investors and third party DoEs, spreading over public and private sectors and over multiple governance levels. Every participant fulfils its own responsibility and cooperates with the others as defined under the CDM framework.

- The CDM EB supervises the entire CDM and is the ultimate point of contact for CDM project participants for the registration of projects and the issue of certified emission reductions.
- In accordance with CDM modalities and procedures, parties participating in CDM must designate a national authority for CDM projects. The registration of a proposed CDM project activity can only take place once approval letters are obtained from the DNA of each party involved.
- A DOE under CDM is either a domestic legal entity or an international organisation accredited and designated by the CDM EB. It has two key functions:
  - A DOE validates and subsequently requests registration of a proposed CDM project activity
  - A DOE verifies emission reductions of a registered CDM project activity, certifies as appropriate and requests the EB to issue CERs accordingly
- A project owner and investors, if available, are responsible for the practical operation of a CDM project, and try to ensure the CERs can be delivered as designed.

The interactions between participants occur in a flat network, which is established on the basis of power and responsibility reconfiguration, rather than the traditional top-down hierarchical system. Therefore, the procedure for CDM projects, i.e. from reconfiguring participants’ power and responsibility, negotiating regulations and requirements and carrying out project actions to monitoring, verifying and approving the amount of CER, can be understood as the dynamics of co-management (see Paper I).
Although there is no clear picture of what a robust governance system should comprise, Paper I suggests that a functioning institution, under which resource systems could endure and develop, should be good for:

- linking different types and levels of organisations
- exchanging resources
- allocating tasks
- reducing transaction costs
- sharing risks
- enhancing conflict resolution mechanisms

(Carlsson and Berkes, 2005; Carlsson and Sandström, 2008).

Researchers are seeking possible solutions in many ways, and co-management is one of the most studied forms of institution. Verified by many empirical studies and experiments on governing commons, successful co-management de facto often arises from adaptive, self-organising processes of learning by doing, rather than being deliberately designed (Carlsson and Sandström, 2008; Cash et al., 2006). In addition, Adger et al. (2005) show that such a process occurs because of the benefits that stakeholders would like to gain by undertaking the action, or the costs they want to avoid by not undertaking it. In other words, successful co-management is highly driven by practical economic benefits or incentives, and this is also the feature characterising CDM projects. As suggested Paper I, studying the governance of CDM projects and comparing it with the theory of co-management can assist in gathering empirical evidence to test and improve the theory of co-management and in applying the knowledge of co-management to better management of climate change mitigation projects.

In general, co-management provides a useful starting point for understanding the ways in which large-scale environmental challenges could be managed across multiple scales and levels (Betsill and Bulkeley, 2006). The discussion on CDM reform in the post-2012 period has already started in the literature, and most people believe that the mechanism has strong conceptual underpinnings and that it should continue after 2012 (Fenhann, 2011; Figueres and Streck, 2009). From a governance perspective, the exercises of CDM in the past ten years have provided valuable knowledge for governing climate change mitigation especially in terms of collaborative actions between stakeholders at different levels and across multiple scales. A future direction to improve the governance of CDM should be toward an increased level of interest and knowledge sharing and a more stringent control system to ensure the effectiveness of collaboration among stakeholders.

### 2.3 Short summary

As shown above, additionality is the core concept in the examination process to eventually decide the registration of a project and the amount of CER credits that should be issued. Throughout recent years, the CDM EB has been working on optimising existing methodologies to ensure the quality in CER assessments, as well as on developing new methodologies to accommodate a broad range of activities and locations covered by CDM (UNFCCC, 2010a).

Theoretically, CDM represents an innovative mitigation instrument worldwide, which was established on strong theoretical foundations. From an emission trading perspective, CDM
involves a large range of participants and is thus able to generate more collective efforts on mitigation; CDM projects are assessed based on individual evaluation of project activities and the related baseline rather than following the ‘cap and trade’ scheme; and CDM by design can encourage a ‘win-win’ situation between industrialised and developing countries. From a governance perspective, CDM can be regarded as practical exercises in co-management, which may be one possible solution for the governance of large-scale environmental challenges such as climate change. The exercises of CDM in the past provided valuable knowledge for governing climate change mitigation in terms of collaborative actions between stakeholders at different levels and across multiple scales, especially when there is no single institution capable of providing a solution.
3 China’s CDM projects and CERs for Annex I countries

In this chapter, China’s CDM projects up to the end of 2010 are reviewed, followed by an analysis on whether CDM could help industrialised countries fulfil their commitments in a cost-effective way. The analysis is composed of two parts, namely: (1) CER prices are compared with the global average mitigation costs and with current carbon market prices in order to investigate the cost-effectiveness of CDM; and (2) the amount of CERs is compared with the commitments of Annex I countries in order to test the provision of CDM.

3.1 Chinese CDM projects

China took a sceptical attitude toward CDM in the early stages, doubting that it would finally become an approach by which the Annex I countries could escape their mitigation responsibility and more importantly whether payment for CDM activities could really be made (Heggelund, 2007; Schroeder, 2009b). After the initial attempts, China changed its position and started to actively support CDM. The Measures for Operation and Management of Clean Development Mechanism Projects in China was enacted on 12 October 2005 to replace the old interim measures, and the regulation on CDM is more clearly defined (National Coordination Committee on Climate Change, 2005).

Figure 3-1 shows China’s CDM projects in the period 2005-2010. There were only three projects registered in the UNFCCC’s database before 2006, accounting for less than 5% in the world (UNFCCC, 2011b). An unpredictable growth in the total amount of projects and related CERs started in 2006, and a peak appeared in the first half of 2009. The fast growth was cooled down by the economic recession that started in the second half of 2008, and the number of projects, as well as CERs, showed a clear decrease in the following year. Note that a considerable period of time is needed for a project from its conception phase to registration, so that the market effects of CDM projects cannot be visualised until half a year later (Fenhann and Staun, 2010). However,
the decrease did not endure for long and the amount of newly registered projects soon returned to increasing in late 2010 (Figure 3-1).

By the end of 2010, there had been a total of 1148 China’s projects registered in the UNFCCC’s database, accounting for 42% of all CDM projects and these projects would annually generate 261.45 million tonnes of CERs, accounting for 62% of the total CER credits worldwide (Figure 3-2). China’s projects dominated the supply side of CDM in both number of projects and CERs, while the other three big developing countries of the ‘BASIC’, i.e. India, Brazil and South Africa, together had supplied 799 projects by the end of 2010, representing less than 17% of the total CERs.

Figure 3-2 Registered CDM projects by host countries by the end of 2010

China’s registered projects cover up 15 categories of activities, within which hydropower projects and HFC23 decomposition projects are the two largest categories in terms of number of projects and
CERs, respectively (Figure 3-3). The categories used in this thesis were taken from the UNEP’s CDM Pipeline Overview (Fenhann, 2011), which contains more details about energy sources than the CDM database.

In terms of number of projects, the three largest categories are hydropower (48.6%), wind power (27.8%) and EE own generation (7.7%), where electricity is produced from waste gas or waste energy (Fenhann, 2011). These numbers are in accordance with China’s recent energy strategy, which aims to significantly promote renewable energy (see Paper III). For example, China’s Renewable Energy Law, which was approved in February 2005 and came into effect in January 2006, sets up a target that 15% of China’s total energy consumption will come from renewable sources by 2020 (NPC, 2009). In contrast, there were only a total of 11 HFC23 decomposition projects in the database, although these made the largest contribution (26.1%) in terms of CERs, followed by hydropower (24.1%) and wind power projects (15.5%). Despite the large capacity of CER generation, there was intensive argument in China at the beginning on whether HFC23 decomposition projects should be allowed under CDM (Heggelund, 2007). Although these projects were accepted under CDM in the end, 65% of the revenues from the CER transfer are taken by the government and used to support other activities on climate change. In contrast, only 2% CER transfer benefits are taken from the CDM projects in priority areas, such as energy efficiency improvement, development and utilisation of new and renewable energy, methane recovery and utilisation, and afforestation projects (Lecocq and Ambrosi, 2007; National Coordination Committee on Climate Change, 2005).

3.2 Cost-effectiveness of CDM projects

From its very beginning, CDM was developed to help industrialised countries obtain cheap reduction credits, regardless of where they are, and this aim still lies at the heart of CDM’s future reform (Figuieres and Streck, 2009; Lecocq and Ambrosi, 2007). In practice, there was not much debate on CDM regarding this issue, since it is generally cheaper to construct low-carbon energy infrastructure in developing countries than to modify or replace existing facilities in industrialised countries (Wara, 2007).

Figure 3-4 shows the average CER prices on the international market in the past few years. Although the average price for CERs on the international market rose rapidly in the period 2004-2008, it was pulled down by the global financial crisis after the second half of 2008, and the price continued to fall down to the 12 US dollars (USD) level in 2009. Meanwhile, some indexed contracts contain floor prices and/or ceiling prices, which prevent the carbon market from large fluctuations and allow risks to be shared between buyers and sellers (Lecocq and Ambrosi, 2007). For instance, China has set the CER floor price at 8 Euros/10 USD, and there seems to be no intention to change this price floor in the near future (Schroeder, 2009b). Due to China’s dominant share in the global CDM market, the floor price plays an important role in preventing the international CDM market from the so-called problem of ‘running to the bottom’ (to be discussed in Chapter 6) (Capoor and Ambrosi, 2007). However, the reduction costs for industrialised countries would be much higher than CER prices if they had to achieve their reductions commitments in domestic emissions. For example, a report from the McKinsey & Company suggested that Sweden would have to implement all measures, with costs of up to 500 Swedish Krona (SEK) (more than 60 USD) per tonne of CO₂e reduction, in order to achieve its commitment under the Kyoto Protocol (Enkvist et al., 2008).
In addition to marginal costs, the latest McKinsey *Global Greenhouse Gas Abatement Cost Curve (Version 2.1)* indicates that technical measures averaging 60-80 Euros per tonne of CO$_2$e would have to be implemented in order to achieve long-term stabilisation of global GHG concentration at 450 parts per million (ppm), corresponding to an expected 2°C temperature increase compared with the current level (Enkvist et al., 2010). Similarly, the Fourth Assessment Report (FAR) of the IPCC (Intergovernmental Panel on Climate Change) previously estimated that the cost of keeping CO$_2$e concentrations below 450 ppm would be 3% of world GDP by 2030 (IPCC, 2007). These costs are annual costs and must be continuously invested in mitigation actions (Heal, 2009).

### Table 3-1 Global average costs for maintaining the GHG concentration at 450 ppm in 2030

<table>
<thead>
<tr>
<th>GDP in 2030 (billion USD)</th>
<th>No-growth</th>
<th>1% growth in GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>58141.50</td>
<td>71653.58</td>
<td></td>
</tr>
<tr>
<td>2% of GDP (billion USD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1162.83</td>
<td>1433.07</td>
<td></td>
</tr>
<tr>
<td>Reduction (billion tonnes CO$_2$e)</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Cost (USD/tonne CO$_2$e)</td>
<td>30.60</td>
<td>37.71</td>
</tr>
</tbody>
</table>


To give a rough sense of these figures, Table 3-1 shows the estimation of global average costs in 2030 for maintaining the GHG concentration at 450 ppm. The estimates adopted a conservative principle, namely: (1) 2%, rather than 3%, of world GDP is used for mitigation; (2) the world economy in terms of GDP is assumed to be unchanged or to grow at a slow rate of 1% per annum after 2009; (3) the total reduction amount, i.e. 38 billion tonnes of CO$_2$e, is taken from the latest McKinsey report and represents an amount larger than what is needed to maintain the
CO\textsubscript{2}e level at 450 ppm; and (4) inflation and discounting issues are not considered. The average annual mitigation cost is 30.60 USD/tCO\textsubscript{2}e in the situation where the global economy in 2030 will remain the same, and the annual cost rises up to 37.71 USD/tCO\textsubscript{2}e when the global GDP will grow by only 1\% per annum. Note that these macro-economic estimates considered all types of mitigation activities, including those low-cost options such as CDM projects contributed by developing countries. Thus, the global average costs for maintaining the GHG concentration at 450 ppm are much higher than current CER prices (cf. Figure 3-4).

A more telling figure than the global average mitigation costs is the current carbon market price, for which the Annex I countries have to pay otherwise to obtain reduction credits. Figure 3-5 shows the comparison of the prices between the three flexible mechanisms, i.e. CDM, EU ETS and JI, in the period 2005-2009. The prices for CDM and JI on the international carbon market were very close in 2005-2009, and both remained markedly lower than the prices for EU ETS in this period. Thus, CERs represent a phenomenal option for industrialised countries to fulfil their obligatory reduction targets in a cost-effective way. However, CDM projects in total provided 211 million tonnes of CO\textsubscript{2}e in 2009, in contrast with 6326 million tonnes of CO\textsubscript{2}e traded under the EU ETS and 26 million tonnes under the JI (Kossoy and Ambrosi, 2010). Consequently, it is necessary to evaluate the total provision of CDM, since the entire effects of CDM would be limited if the total supply was too small to meet the mitigation demand, despite the cheap price for CERs.

### 3.3 Provision of China’s CDM projects

To test the provision, the commitments of Annex I countries under the UNFCCC were compared with the amount of CERs generated by China’s CDM projects. The industrialised countries that participated in China’s CDM projects were considered and the data on their emissions were obtained from the UNFCCC’s *National Emission Inventory 2010* (UNFCCC, 2010c). The number of registered CERs was used in this study to calculate the amount of CERs, due to its solid status and good accessibility. However, it has been noted that the number of issued CER credits is a more precise option than the registered amount because of the ‘issuance delay’ of 0.5-1 year on average, which refers to the time from the date when a project is registered to the date
when its first set of CERs is issued, and because of the ‘inaction’ problem of registered projects arising for many reasons during the construction and operation phases (Fenhann and Staun, 2010). Fenhann and Staun (2010) introduced the concept of ‘issuance success’, which is defined as the issued CERs divided by the expected CERs of registered projects, and suggested that the issuance success reaches 96.8% for all registered projects. Therefore, the registered amount of CERs is an eligible alternative to the issued amount in practice.

By the end of 2010, there had been 19 industrialised countries participating in China’s CDM projects. Their GHG emission changes in 2008 compared with corresponding baseline levels can be seen in Figure 3-6, where red bars indicate emission increases and green bars indicate decreases. These emissions were calculated on the basis of energy consumption, and mitigation credits purchased from flexible mechanisms were not considered (UNFCCC, 2010c). The mitigation commitments of these countries were defined under the Kyoto Protocol (UNFCCC, 1998), as indicated by the blue bars in Figure 3-6. Note that the individual mitigation compliance varies among these countries, and especially the European Union Member States, which agreed on a ‘burden sharing agreement’, redistributing the European Community’s overall mitigation task among each other (Berger et al., 2007; Gugele et al., 2002).

Only five countries, namely Sweden, UK, France, Germany and Finland, achieved their mitigation commitments in 2008, while the other 14 countries failed to meet their commitments. On aggregate, the total GHG emissions of these 19 countries were 6005.9 million tonnes of CO₂e in 2008, which represented a 2.1% decrease compared with the 1990 level and was much higher than the committed 8% (Figure 3-6).
**Figure 3-6 Emission changes in industrialised countries in 2008 compared with the baseline level in 1990**


Subsequently, the individual CER credits for each country had to be determined. There are many CDM projects involving multiple Annex I participants, while their individual CERs in these projects are unknown. A simple method was adopted in this study to calculate every participant’s CER credits:

\[ CER_A = \sum_i \frac{CER_i}{n} \]

where \( i \) refers to a project in which country \( A \) participated, and \( n \) is the total number of participants in project \( i \). The contribution of CDM to country \( A \)’s commitment is defined as:

\[ \text{Contribution}_A = -\frac{CER_A}{\text{Commitment}_A}, \]

if country \( A \) has committed itself to a certain amount of reduction compared with the baseline level; or:

\[ \text{Contribution}_A = \frac{CER_A}{\text{Actual Increase}_A - \text{Committed increase}_A}, \]

if country \( A \) has been allowed to increase its emissions by a certain amount, or to maintain its emissions at the baseline level.

Table 3-2 Contribution of China’s CDM projects to industrialised countries’ mitigation commitments under the Kyoto Protocol

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of projects</th>
<th>CERs (million tonnes)</th>
<th>Committed amount (million tonnes)</th>
<th>Emission change in 2008 cf. baseline (million tonnes)</th>
<th>CDM contribution to mitigation target (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>32</td>
<td>3.72</td>
<td>-10.16</td>
<td>8.47</td>
<td>36.65%</td>
</tr>
<tr>
<td>Belgium</td>
<td>7</td>
<td>0.34</td>
<td>-10.75</td>
<td>-10.14</td>
<td>3.12%</td>
</tr>
<tr>
<td>Canada</td>
<td>8</td>
<td>6.87</td>
<td>-35.51</td>
<td>142.69</td>
<td>19.34%</td>
</tr>
<tr>
<td>Denmark</td>
<td>12</td>
<td>2.28</td>
<td>-14.79</td>
<td>-4.80</td>
<td>15.41%</td>
</tr>
<tr>
<td>Finland</td>
<td>6</td>
<td>1.54</td>
<td>0</td>
<td>-0.16</td>
<td>-947.48%</td>
</tr>
<tr>
<td>France</td>
<td>17</td>
<td>4.27</td>
<td>0</td>
<td>-33.24</td>
<td>-12.85%</td>
</tr>
<tr>
<td>Germany</td>
<td>71</td>
<td>9.15</td>
<td>-262.76</td>
<td>-267.51</td>
<td>3.48%</td>
</tr>
<tr>
<td>Ireland</td>
<td>1</td>
<td>2.62</td>
<td>7.12</td>
<td>12.68</td>
<td>47.14%</td>
</tr>
<tr>
<td>Italy</td>
<td>25</td>
<td>8.04</td>
<td>-33.61</td>
<td>24.44</td>
<td>23.92%</td>
</tr>
<tr>
<td>Japan</td>
<td>190</td>
<td>44.38</td>
<td>-76.12</td>
<td>13.21</td>
<td>58.30%</td>
</tr>
<tr>
<td>Liechtenstein</td>
<td>1</td>
<td>0.21</td>
<td>-0.02</td>
<td>0.03</td>
<td>1157.25%</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>4</td>
<td>0.09</td>
<td>-3.67</td>
<td>-0.62</td>
<td>2.33%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>210</td>
<td>32.92</td>
<td>-12.72</td>
<td>-5.09</td>
<td>258.79%</td>
</tr>
<tr>
<td>Norway</td>
<td>15</td>
<td>2.47</td>
<td>0.50</td>
<td>4.66</td>
<td>59.44%</td>
</tr>
<tr>
<td>Portugal</td>
<td>3</td>
<td>0.16</td>
<td>16.01</td>
<td>19.09</td>
<td>5.31%</td>
</tr>
<tr>
<td>Spain</td>
<td>23</td>
<td>3.92</td>
<td>42.77</td>
<td>121.28</td>
<td>4.99%</td>
</tr>
<tr>
<td>Sweden</td>
<td>154</td>
<td>14.34</td>
<td>2.90</td>
<td>-8.38</td>
<td>-127.18%</td>
</tr>
</tbody>
</table>
Table 3-2 shows the results regarding: (1) the amount of CDM projects and related CERs for each of the industrialised country by the end of 2010, (2) the mitigation commitment of each industrialised country and its emission reductions in 2008, and (3) the contribution of China’s CDM projects to the mitigation commitments of industrialized countries. Note that the latest data for each country’s actual emissions were the 2008 figures, while the CER statistics had been updated to the end of 2010. By the end of 2010, China has supplied a total of 259.22 million tonnes of CERs, which amounted to 52.70% of the total mitigation commitments of the industrialised countries. The CERs were over twice the domestic reduction efforts of the industrialised countries, i.e. 126.09 million tonnes (Table 3-2). Taking CERs into account, a total of eight countries achieved their mitigation commitments in 2008; or in other words, three more countries, namely Liechtenstein, the Netherlands and Switzerland, met their mitigation commitments when their CDM credits were taken into account (Figure 3-6). These numbers show that the CDM is able to greatly help industrialised countries fulfil their mitigation commitment.

Table 3-3 Interest of industrialised countries in China’s CDM

<table>
<thead>
<tr>
<th>Country</th>
<th>High Interest</th>
<th>Medium Interest</th>
<th>Low Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interest *</td>
<td>Country</td>
<td>Type I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interest</td>
<td>Interest</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>Liechtenstein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Japan</td>
<td>Finland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ireland</td>
<td>Switzerland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Austria</td>
<td>Netherlands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Belgium</td>
<td>UK</td>
</tr>
</tbody>
</table>

Note: * A negative value means that an Annex I country has committed itself to reducing its annual emissions compared with the baseline level; a positive value means that a country has been allowed to increase its emissions within a certain amount over the baseline level; and 0 means that a country has committed to keeping its emissions the same as its baseline level.


Table 3-2 also shows the huge differences in the individual interests in CDM between different countries, while there is unfortunately not any clear general correlation between the CER amount and a country’s commitment, or its baseline emissions. A number of issues can affect the attractiveness of CDM on the supply side, the three most important factors being CDM potential, institutional capacity and general investment environment of a host country (Foot, 2004; Jung, 2006; Schroeder, 2009a). In addition, other issues such as transaction costs, information...
availability, overall economic situation and business relationship between buyers and sellers can affect the decision in practice (Bréchet and Lussis, 2006; Chadwick, 2006; Diakoulaki et al., 2007).

To provide an insight into the interest in CDM on the demand side, the CDM contributions to the 19 countries were ranked and placed into three groups (Table 3-3). In the group of high interest, six countries (Liechtenstein, Finland, Switzerland, the Netherlands, Sweden and UK) had purchased more credits than their mitigation commitments. Looking from another angle, these countries continued to invest in CDM projects when their mitigation targets had already been met. This fact seems contradictory to CDM’s role of saving costs, but an explanation can be that purchasing more credits may help these countries to deal with the uncertainties relating to the problem of ‘issuance success’, i.e. some of the registered projects might never produce CERs owing to lack of finance or other problems (Fenhann, 2011; Fenhann and Staun, 2010). Another explanation can be that these countries re-sell part of the credits on the international carbon market to gain extra benefits, rather than only meeting their own mitigation targets (Foot, 2004). Note that EU Member States are allowed to use up to 10% CDM/JI credits to offset their allowance under the EU-ETS (European Commission, 2004), but there were no detailed figures relating to this issue in existing studies.

The medium interest group consisted of four countries, namely Norway (59.44%), Japan (58.30%), Ireland (47.14%) and Austria (36.65%). It is interesting to note that both Norway and Ireland have been allowed to increase their emissions compared with associated baselines, while both were not able to limit their emissions within the committed ranges, even considering the credits from CDM. Japan is one of the largest buyers of CERs in the world, but the contribution of CDM to achieving its mitigation commitment was limited due to its large amount of emissions. Austria has committed itself to cutting down its emissions by 13% compared with the baseline, while its actual emissions in 2008 increased by 10.83% (8.47 million tonnes). Even considering the CER credits, Austria was still far from the committed emission level in 2008.

Relatively low interest was found in France, Germany, Italy, Canada, Denmark, Portugal, Spain, Belgium and Luxembourg, in which the contributions were smaller than 30% (Table 3-3). Within these countries, France and Germany did not need to purchase many credits since they both had achieved their mitigation commitments without purchasing reduction credits. For the rest countries, a possible reason is that a country may have bought mitigation credits from other sources, e.g. CDM projects in other developing countries or on the secondary market, and/or through other mechanisms such as JI and ET. For example, Canada had participated in 52 CDM projects by the end of 2010, of which only eight projects were China’s CDM project activities and 44 projects were located in other developing countries (UNFCCC, 2011b). In fact, the competition between different CDM project activities, known as the ‘running to the bottom’ problem, and the competition between CDM project activities and other tradable mechanisms had already been highlighted in the early phase of the Kyoto Protocol (Klepper and Peterson, 2004; 2006; Yamin et al., 2001; Zhang, 2004). Nevertheless, attention must be given to those countries that did not try to either limit their domestic emissions or invest in reduction credits.

3.4 Short summary
This chapter focused on China’s CDM projects to analyse the cost-effectiveness of the mechanism. Generally, it can be concluded that CDM is able to provide a significant amount of
CERs at a rather low price, i.e. the aim of CDM in terms of cost-effectiveness is fulfilled. Specifically, China had supplied a total of 259.22 million tonnes of CERs by the end of 2010, which amounted to 52.70% of the total mitigation commitments of the industrialized countries involved. In fact, these reductions were over twice the domestic reduction efforts of the industrialised countries, i.e. 126.09 million tonnes. Taking CERs into account, a total of eight countries achieved their mitigation commitments in 2008. Given that only China’s CDM projects were considered in the study and that new CERs have been continuously accredited to the account of industrialised countries before 2012, the overall contribution of CDM to the current climate change mitigation target will keep increasing. In addition, note that the verdict was based on registered CERs, rather than issued amounts. While there is high issuance success at present, it is very important to ensure that registered projects constantly generate CERs as designed throughout their whole crediting periods.

However, the current CDM does not establish a universal cap on the world’s total emissions and can be regarded as an interim mechanism. In the meantime, a large number of low-cost mitigation potentials in developing countries have been developed as CDM projects. This has raised concerns about the impacts of CDM project activities on the domestic emissions of developing countries and on their mitigation potentials. The discussion has become increasingly relevant to the negotiations on the post-2012 international climate change mitigation regime. Thus, the following chapter examines the relationship between China’s CDM projects and its mitigation target.
4 CDM and China’s mitigation strategy
This chapter starts by analysing China’s new mitigation target, i.e. to reduce the CO\textsubscript{2} intensity of GDP by 40-45\% by 2020 compared with the 2005 level. A conceptual analysis is then made of CDM’s mitigation effects in industrialised countries and developing countries, and the effects generated by China’s CDM projects are compared with China’s emissions to examine the domestic relevance of CDM.

4.1 China’s CO\textsubscript{2} mitigation target
No official data on China’s CO\textsubscript{2} emissions have been published by the Chinese government to date and thus this study used the data from the International Energy Agency (IEA), which has kept updating and revising its annual reports using a consistent method. Specifically, the original data were taken from the IEA energy balance statistics, which focused on the CO\textsubscript{2} emissions from fuel combustion, and the emission factors and default methods were taken from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IEA, 2010). Consequently, the emissions in the IEA report represent a part of a country’s total emissions, i.e. energy-related emissions accounted for about 83\% of total GHG emissions globally (UNFCCC, 2010b). In addition, the average ratio for the IEA’s estimates in 1990-2008 was 78.83\% of total GHG emissions, a figure obtained by comparing the aggregated IEA estimates for the 19 industrialized countries that participated in China’s CDM with their total emissions in the National Inventory Submissions to the UNFCCC. Therefore, China’s total CO\textsubscript{2} emissions were calculated in this thesis by enlarging the IEA figures using a factor of 80\%.

![Figure 4-1 China’s CO\textsubscript{2} emissions, 1990-2008](http://www.iea.org/co2highlights/CO2highlights.pdf)


Note: China’s total CO\textsubscript{2} emissions equal the emissions from fuel combustion divided by 80\%.
Figure 4-1 shows China’s CO₂ emissions from fuel combustion (blue line) and total CO₂ emissions (red line) in the period 1990-2008. China’s emissions increased very rapidly in the past 20 years and the exponential growth, especially in the last decade, has made China the largest CO₂ emitter in the world (IEA, 2010; The Netherlands Environmental Assessment Agency, 2007). However, China’s per capita emissions still remain at a low level (Figure 4-2), especially when considering the cumulative emissions throughout the history of industrialisation, which are the main reason for anthropogenic climate change (Houghton, 2001; IPCC, 2001). Complying with the ‘common but differentiated’ principle, China does not need to undertake any reduction responsibility in the current Kyoto Protocol regime. However, China’s must limit the rapid growth in its contemporary emissions, which will otherwise create great challenges to the environment and development in the future (Oberheitmann, 2010).

![Figure 4-1](image_url)

**Figure 4-1** CO₂ emissions from fuel combustion and total emissions in China (1990-2008)


Figure 4-2 shows China’s per capita emissions in the period 1990-2008, with the values for India, USA, the Annex I countries and the world’s average included for comparison. Due to the rapid growth in total emissions, China’s per capita CO₂ emissions also increased very fast in the last decade and reached **4.91 tonnes per capita in 2008**, which surpassed the world’s average, although it was still less than half the level of the Annex I countries (Figure 4-2). The huge amount of emissions and their unpredictable growth reflect China’s heavy demand for energy, which is sustaining China’s current economic growth, social stability and development (Heggelund, 2007). In the meantime, China’s development is allowing the country to take more responsibilities in international affairs, including the global collective actions on climate change mitigation. The Chinese government established a national strategic target regarding energy efficiency in the 11th Five-Year Social and Economic Development Programme (2006-2010), namely to reduce the energy use per unit of economic output by 20% in 2010 compared with 2005 (Heggelund, 2007). By 2009, China’s energy consumption per unit GDP had decreased by 15.60% compared with
the 2005 level (Table 4-1) and according to Li Yizhong, the former Minister of Industry and Information Technology of China, this target had been met in 2010 (Xinhuanet, 2010).

Before the Copenhagen Summit (COP15) in 2009, the Chinese government announced a more straightforward climate change mitigation target, i.e. to reduce CO₂ emissions per unit GDP by 40-45% by 2020 compared with the 2005 level. At the COP15, the Chinese Prime Minister emphasised that any Chinese mitigation strategy must consider domestic economic development, while the mitigation target would be pursued without referring to any other countries or relating to any other conditions (see Paper IV).

To determine this target, China’s total CO₂ emissions as shown in Figure 4-1 and data on China’s GDP taken from the China Statistical Yearbook and adjusted to 2005 prices were used (IEA, 2010; National Bureau of Statistics of China, 2009). The CO₂ emissions per unit GDP dropped from 0.64 kg CO₂/RMB in 1990 to 0.33 kg CO₂/RMB in 2000, and remained relatively stable thereafter (Table 4-1). In 2005, the CO₂ emissions per unit GDP went up to the highest level in the last 10 years, i.e. 0.34 kg CO₂/RMB, and a 40% decrease will therefore require the CO₂ intensity of GDP to decline to 0.21 kg CO₂/RMB.

Table 4-1 China’s CO₂ emissions intensity in relation to GDP and population, 1990-2008

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂/GDP (kg CO₂/RMB using 2005 prices)</td>
<td>0.64</td>
<td>0.49</td>
<td>0.33</td>
<td>0.31</td>
<td>0.30</td>
<td>0.32</td>
<td>0.34</td>
<td>0.34</td>
<td>0.34</td>
<td>0.32</td>
<td>0.31</td>
<td>*</td>
</tr>
<tr>
<td>CO₂/Population (tonnes)</td>
<td>2.42</td>
<td>3.08</td>
<td>3.00</td>
<td>3.02</td>
<td>3.22</td>
<td>3.70</td>
<td>4.37</td>
<td>4.84</td>
<td>5.33</td>
<td>5.71</td>
<td>6.13</td>
<td>*</td>
</tr>
<tr>
<td>CO₂/capita**</td>
<td>0.23</td>
<td>0.17</td>
<td>0.13</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.13</td>
<td>0.13</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>EC/GDP (kg SCE/RMB)***</td>
<td>0.23</td>
<td>0.17</td>
<td>0.13</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.13</td>
<td>0.13</td>
<td>0.12</td>
<td>0.12</td>
<td>0.11</td>
<td>0.11</td>
</tr>
</tbody>
</table>


Note: * The data on CO₂ emissions in 2009 were not available at the time of writing the thesis.
** The per capita emissions are different from the IEA data (Figure 4-2) due to the different methodologies adopted.
*** In the China Statistical Yearbook, standard coal equivalent (SCE) is used as the unit of energy.

The next question is how great the reduction/increase would be if the target were to be achieved in 2020. The answer depends on: (1) how fast China’s GDP will continue to grow until 2020, and (2) how much CO₂ will be annually emitted in the business-as-usual (BAU) scenario until 2020. The impacts of other variables, e.g. changes in the exchange rate, were not considered in this estimation.

A review of China’s GDP in the period 1991-2010 (Figure 4-3), shows that China experienced double-digit economic growth in the last 20 years and that the average growth rate reached 10.53% per annum. The worst situation occurred in 1998-1999, when China was involved in the Southeast Asian financial crisis, and the second drop resulted from the 2008 global financial crisis. However, China soon recovered from the latter crisis and the GDP increase returned from 8.61% in 2009 to 10.3% in 2010 (NBSC, 2011). Considering these two figures, China’s future GDP was projected with growth rates of 8% and 10% per annum in this study.
Population and economy are the two major macro-variables driving energy consumption and related CO$_2$ emissions (Zhou et al., 2008). Therefore, the relationship between two indicators, GDP per capita (GDP/capita) and CO$_2$ emissions per capita (CO$_2$/capita), was determined (Figure 4-4), and then the BAU scenarios with each economic growth rate were established on the basis of this relationship.

The relationship between GDP/capita and CO$_2$/capita in 2000-2008 can be very well modelled by a linear regression (Figure 4-4). It should be noted that China has been making an increasing amount of effort on energy efficiency and climate change mitigation since 2000 (see Paper III), and this gradually slowed the growth rate of per capita CO$_2$ emissions as the per capita GDP
increased. Consequently, a polynomial regression can provide a slightly better fit for the relationship between GDP/capita and CO$_2$/capita in the period 2000-2008. However, this thesis chose to follow linear regression rather than quadratic regression because the polynomial regression indicates a turning point in per capita CO$_2$ emissions between 2012 and 2013, which is unrealistic given China’s present economic growth and relatively stable population.

Following the linear relationship between GDP/capita and CO$_2$/capita (Figure 4-4), the CO$_2$ emissions in the BAU scenarios, target emissions and corresponding reductions in 2010-2020 are shown in Table 4-2. In addition, the mitigation target is assumed to be achieved at a constant rate, i.e. the CO$_2$ emissions per unit GDP will decrease by 0.01 kg CO$_2$/RMB annually in 2010-2020.

<table>
<thead>
<tr>
<th>(million tonnes CO$_2$)</th>
<th>BAU (8%)</th>
<th>Target (8%)</th>
<th>Reduction</th>
<th>BAU (10%)</th>
<th>Target (10%)</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>9914.43</td>
<td>9588.65</td>
<td>325.77</td>
<td>10098.03</td>
<td>9766.22</td>
<td>331.81</td>
</tr>
<tr>
<td>2011</td>
<td>10706.17</td>
<td>10002.68</td>
<td>703.49</td>
<td>11106.36</td>
<td>10376.58</td>
<td>729.79</td>
</tr>
<tr>
<td>2012</td>
<td>11561.24</td>
<td>10421.58</td>
<td>1139.66</td>
<td>12215.50</td>
<td>11011.34</td>
<td>1204.16</td>
</tr>
<tr>
<td>2013</td>
<td>12484.71</td>
<td>10843.49</td>
<td>1641.22</td>
<td>13435.51</td>
<td>11669.29</td>
<td>1766.21</td>
</tr>
<tr>
<td>2014</td>
<td>13482.05</td>
<td>11266.20</td>
<td>2215.85</td>
<td>14777.48</td>
<td>12348.72</td>
<td>2428.76</td>
</tr>
<tr>
<td>2015</td>
<td>14559.16</td>
<td>11687.15</td>
<td>2872.01</td>
<td>16253.62</td>
<td>13047.35</td>
<td>3206.27</td>
</tr>
<tr>
<td>2016</td>
<td>15722.44</td>
<td>12103.35</td>
<td>3619.09</td>
<td>17877.32</td>
<td>13762.21</td>
<td>4115.12</td>
</tr>
<tr>
<td>2017</td>
<td>16978.77</td>
<td>12511.34</td>
<td>4467.43</td>
<td>19663.36</td>
<td>14489.56</td>
<td>5173.80</td>
</tr>
<tr>
<td>2018</td>
<td>18335.60</td>
<td>12907.15</td>
<td>5428.45</td>
<td>21627.96</td>
<td>15224.77</td>
<td>6403.19</td>
</tr>
<tr>
<td>2019</td>
<td>19800.97</td>
<td>13286.22</td>
<td>6514.75</td>
<td>23788.98</td>
<td>15962.12</td>
<td>7826.85</td>
</tr>
<tr>
<td>2020</td>
<td>21383.56</td>
<td>13643.33</td>
<td>7740.23</td>
<td>26166.05</td>
<td>16694.70</td>
<td>9471.35</td>
</tr>
<tr>
<td>Sum</td>
<td>164929.10</td>
<td>128261.14</td>
<td>36667.96</td>
<td>187010.17</td>
<td>144352.87</td>
<td>42657.30</td>
</tr>
</tbody>
</table>


As shown in Table 4-2, if the mitigation target is met, China’s absolute emissions in 2020 would increase by 42.29% and 70.94% compared with the present level in 2010, given annual growth in GDP of 8% and 10%, respectively. Even so, to reach this target China would have to decrease its cumulative CO$_2$ emissions by 36667.96 and 42657.30 million tonnes compared with the BAU scenarios in 2010-2020. This reduction is more than one quarter of Chinese cumulative emissions in the BAU scenarios. In contrast, the total reduction commitment of the Annex I countries according to the Kyoto Protocol is less than 1000 million tonnes of CO$_2$ emissions per annum (UNFCCC, 1998; 2010c). Nevertheless, the mitigation target announced by the Chinese government is ambitious, although it refers to a comparative level rather than an absolute amount.

### 4.2 Additionality of CDM in the Annex I countries and developing countries

Critics of CDM regarding its additionality and environmental efficiency claim that it lacks a cap on total emissions and thus fails to produce real reductions, that it is not sufficient to lower the
emission trajectories of developing countries in the long run, and that it is an inefficient subsidy as regards HFC23 decomposition projects (Liverman, 2009; Paulsson, 2009; Pearson, 2007; Wara, 2007). On the other hand, some studies have pointed out that CDM could play an important role in directing investments into renewable energy in developing countries (Lecocq and Ambrosi, 2007; Lewis, 2010). To address these concerns, this section adopts a conceptual approach to compare the baseline, the current situation, the BAU situation and the forecast, with and without CDM.

**Annex I countries**

![Diagram showing emissions and CERs for Annex I countries](image)

**Developing countries**

![Diagram showing emissions and CERs for developing countries](image)

**Figure 4-5 CERs from developing countries to the Annex I countries**

Note: The scales of emissions and reductions are different for the Annex I countries and the developing countries. The same ‘CERs’ produced in developing countries are counted in the accounts of Annex I countries, as shown by the red dashed lines in the diagram.

Figure 4-5 shows the rationale of CDM and its impacts on industrialised countries and developing countries. By implementing mitigation projects in developing countries, a certain amount of reductions can be avoided and further used by the Annex I countries to offset part of their reduction compliance (as indicated by the red dashed lines in Figure 4-5). Section 3.3 showed that CDM can help the Annex I countries achieve their mitigation compliances and that the total amount of CERs at present is even larger than their domestic efforts. Given that new CDM projects will continue to be approved and more CERs accredited before 2012, very few domestic mitigation efforts are needed for the Annex I countries (Figure 4-5). In the meantime, CDM projects also help press down the emission trajectories in developing countries, especially in the long run (as indicated by the black dashed arrows in Figure 4-5) (Huang and Barker, 2008), although the size of additionality, i.e. the amount of avoided emissions that would otherwise occur, depends on how the BAU situation is defined. Therefore, CDM creates a double mitigation effect, i.e. assisting industrialised countries in their current mitigation commitments and helping developing countries limit their emission growth, especially in the long run.
As the same CERs have a double mitigation effect, in the Annex I countries and developing countries, the question arises as to whether these CERs are subject to the problem of double counting. The answer is no, under the current mitigation regime. Although CDM avoids emissions that would otherwise occur, CDM project activities are simultaneously responsible for a certain amount of net emissions in practice (indicated by the red area in Figure 4-6) (Hepburn, 2007). The avoided emissions (CERs) are transferred to the mitigation accounts of the Annex I countries, while the net emissions are included in the domestic emissions of the developing countries. Under the current mitigation regime, developing countries do not undertake any compulsory mitigation responsibilities, and some developing countries, e.g. China and India, have announced self-restricting targets of reducing emission intensity. The targets in terms of emission intensity are defined on the basis of actual emissions, where the net emissions (the red area in Figure 4-6) from CDM are included in the target, while the CERs (the blue area in Figure 4-6) are not. Therefore, it can be concluded that CDM makes a double mitigation effect, in industrialised and developing countries, without being subject to the problem of double counting.

It is true that the CDM does not involve any cap on emissions (Figure 4-5). However, this does not change the fact that CDM has achieved its mitigation purpose, since it has successfully brought developing countries into the current international climate change mitigation regime and provided cheap reductions to the world. To force developing countries to undertake compulsory reduction commitments similar to those made by industrialised countries is more than the capacity of any mitigation mechanism at present and, more importantly, it violates the ‘common but differentiated’ principle upon which the whole climate change mitigation regime relies (Criqui et al., 2003; Oberheirman, 2010). Industrial development and improving the standard of living are placed far ahead of climate change mitigation in most developing countries and therefore gradually incorporating developing countries with incrementally stringent mitigation targets would be more practical (Clémençon, 2008; Figueres and Streck, 2009).

Last but not least, a large number of critics of CDM concentrate on HFC23 decomposition projects. Wara (2007) argued that HFC23 could be reduced at much a lower cost than the CER price, and proposed to create an alternative mechanism for reducing HFC23. However, given CDM’s role of providing cheap reduction opportunities no matter what and where they are, there
is no reason to over-blame HFC23 projects. The situation that HFC23 projects are preferred under CDM reflects the rule of a voluntary market, on which the whole mechanism is founded (Lecocq and Ambrosi, 2007). Another consideration is that many criticisms are based on case studies of individual projects rather than a comprehensive analysis of a large number of projects (Liverman, 2009). Compared with other types of projects, HFC23 decomposition projects can produce more indirect benefits, an issue dealt with in the next chapter.

4.3 CDM and Chinese mitigation target

Previous studies suggested that the reduction achievement of CDM is just ‘a small drop in the bucket’, although the mechanism plays an important role in redirecting the energy investment in developing countries (Lewis, 2010; Schroeder, 2009b). This section attempts to quantify the effects of CDM projects on China’s mitigation target in the period 2005-2012.

As shown in Figure 4-6, the contribution of CDM to China’s emission control can be calculated as:

$$\text{CDM’s Contribution}_t = \frac{\text{CERs}_t}{\text{CERs}_t + \text{China’s actual emissions}_t}$$

The effects of CDM projects on limiting China’s overall emissions in year t can be calculated as the CERs accredited in year t divided by the total emissions if CDM had not existed. China’s actual emissions in 2005-2012 were taken from the study described in Section 4.1, where the mitigation targets in terms of CO₂ per unit GDP in 2010-2012 were assumed to have decreased to meet the final mitigation target in 2020. The CERs in 2005-2010 were taken from the PDDs of CDM projects, and three profiles, i.e. conservative, neutral and optimistic, were established to represent different forecasts of CERs in 2011-2012 (Table 4-3). The forecasts of future CERs roughly follow the current trend of CDM projects, namely 40 million tonnes of CO₂e per annum in the conservative profile, 50 million tonnes per annum in the neutral profile and 60 million tonnes per annum in the optimistic profile. At the time of writing the thesis, a total of 69 projects, representing 11.22 million tonnes of CERs, had been registered in the CDM database in the first two months of 2011, indicating a similar trend to that forecast (UNFCCC, 2011b). In addition, the results are slightly amplified due to the problem of ‘issuance delay’, i.e. it often takes a couple of months for the CERs to start being issued (Fenhann, 2011; Fenhann and Staun, 2010).

Table 4-3 shows the mitigation effects of CDM projects in China in the period 2005-2012. The total effects of CDM have kept increasing since 2005 because projects continuously reduce CO₂ emissions during their crediting period, which is usually seven years or longer. By the end of 2010, the total mitigation effects of CDM had reached 2.6% of China’s total CO₂ emissions, and this figure will rise to 3% before the end of 2012 in both scenarios (Table 4-3). In addition, the faster China’s economy grows in future, the smaller the mitigation effects CDM project activities can make. This is because a fast-growing economy is associated with a fast increase in GHG emissions, while the total volume of CERs remains comparatively stable every year.

<table>
<thead>
<tr>
<th>Table 4-3 Mitigation effects of CDM projects in China, 2005-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual CERs (million tonnes of CO₂e)</td>
</tr>
</tbody>
</table>

4
Table 4-4 CDM projects and China’s electricity generation, 2005-2010

<table>
<thead>
<tr>
<th>Year</th>
<th>2005 (Mkwh)</th>
<th>2006 (Mkwh)</th>
<th>2007 (Mkwh)</th>
<th>2008 (Mkwh)</th>
<th>2009 (Mkwh)</th>
<th>2010 (Mkwh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total amount of electricity</td>
<td>2500260</td>
<td>2865726</td>
<td>3281553</td>
<td>3466882</td>
<td>3650623</td>
<td>4206500</td>
</tr>
<tr>
<td>Electricity from renewable sources</td>
<td>399836</td>
<td>441280</td>
<td>496490</td>
<td>608410</td>
<td>599938</td>
<td>807800</td>
</tr>
<tr>
<td>Electricity from CDM projects</td>
<td>97.62</td>
<td>2828.46</td>
<td>20497.53</td>
<td>67467.51</td>
<td>140762.77</td>
<td>206325.00</td>
</tr>
<tr>
<td>Contribution to the total</td>
<td>0.02%</td>
<td>0.10%</td>
<td>0.62%</td>
<td>1.95%</td>
<td>3.86%</td>
<td>4.90%</td>
</tr>
<tr>
<td>Contribution to renewable electricity</td>
<td>0.02%</td>
<td>0.64%</td>
<td>4.13%</td>
<td>11.09%</td>
<td>23.46%</td>
<td>25.54%</td>
</tr>
</tbody>
</table>

To further examine the criticisms of CDM’s effects on China’s energy investment, the amount of electricity generated by CDM projects was compared with China’s power generation. The majority of China’s electricity comes from thermal power, which is based on fossil fuel combustion. Apart from thermal power, China’s electricity mainly comes from nuclear power and renewable energy, including, e.g. hydropower, wind power, and others (Table 4-4).
Nevertheless, CDM is currently playing an important role in promoting China’s energy structure, namely in the way of stimulating the development of renewable energy. Taking hydropower and wind power as an example, the total amount of hydropower and wind power reached 662.2 and 43.0 trillion watt hours in 2010, respectively, and CDM projects delivered about 11% of hydropower and over 90% of wind power (Figure 4-7).

\[ \text{Figure 4-7 CDM projects and China's hydropower and wind power generation in 2010} \]

### 4.4 Short summary

China’s domestic mitigation target, which is based on CO₂ emissions per unit GDP, leaves the uncertainty in China’s future emissions very much to China’s future economic growth. Given annual growth in GDP of 8% and 10%, respectively, China would have to reduce its emissions by over 3667.96 and 42657.30 million tonnes of CO₂ in its cumulative emissions to reach the reduction target of 40% by 2020 (Table 4-2). The cumulative amount of reductions is over one-quarter of China’s total emissions in any scenario, although the absolute emissions would still be over 40% more than the current level (Table 4-2).

As regards CDM, the conceptual analysis of CDM carried out in this chapter showed that CDM has a double mitigation effect, in both industrialised and developing countries, without being subject to the problem of double counting under the current mitigation regime.

Quantitative comparison of CERs against China’s total emissions showed that the contribution of CDM would reach about 3% by 2012, which is small. However, CDM’s effects on stimulating China’s renewable energy is significant, with over 25% of the power generated by renewable resources coming from CDM project activities in 2010 (Table 4-4). Specifically, about 11% of hydropower and 93% of wind power were generated by CDM projects. In addition, the effects of CDM have been steadily increasing due to the rapid growth in CDM projects in recent years.
5 CDM and sustainable development

Critical questions regarding the sustainability of CDM projects include how the scope of sustainable development is defined and how the impacts within this scope are assessed (see Paper II). By definition, sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987). As mentioned in Chapter 1, it is difficult to define sustainable development in the context of CDM without controversy. This thesis thus reviewed the literature to establish the scope of sustainable development on the basis of previous studies. With respect to assessment methods, a number of forward-looking studies before 2001 concluded that CDM projects would make ‘potential’, ‘theoretical’ or ‘possible’ contributions to sustainable development in host countries. These studies were subject to an obvious lack of empirical evidence, as it was too early for sufficient data to be available (Olsen, 2007). Since 2001, researchers have started to use a number of approaches to study CDM projects in terms of their impacts on sustainable development in developing countries. These approaches in general include quantitative methods, e.g. CBA of the co-impacts, or ‘ancillary impacts’, which refers to various economic, environmental and social impacts apart from GHG reduction, simultaneously caused by climate change mitigation activities (Aunan et al., 2006; Aunan et al., 2004; Cao et al., 2008; Disch, 2010; Haines et al., 2006; Vennemo et al., 2006) and qualitative (or semi-quantitative) methods, e.g. MCA and meta-CDM (Heuberger et al., 2007; Kolshus et al., 2001; Olsen and Fenhann, 2008; Sutter and Parreño, 2007). However, none of these methods has been able to evaluate CDM projects unequivocally in terms of sustainable development. Instead of developing a new method, this chapter reviews existing methods and then applies the CBA and AHP methods to China’s CDM projects. In Section 5.3.3, the pros and cons of the two methods are summarised and the results from the studies are generalised to address the concern about sustainable development.

5.1 Brief literature review

Systematic studies of CDM’s contribution to sustainable development can be traced back to the beginning of the 2000s. Although the studies before 2001 were subject to the problem of lack of empirical evidences, they were commonly optimistic about the effects of CDM on sustainable development, while critically raising the question of how and by how much CDM projects could contribute to sustainable development (Olsen, 2007).

An important comprehensive study in the early stage was made by Kolshus et al. (2001), who started to assess CDM’s impacts on sustainable development using criteria and indicators. They proposed 18 non-carbon criteria representing environmental, development and equity issues, and examined energy-related CDM projects against these criteria. However, the assessment was done as a checklist and the results were left qualitative, without scores assigned. The checklist method was later adopted by Olsen and Fenhann (2008), who developed a comprehensive scope of sustainable development with 13 delimited criteria and analysed 744 projects in the CDM pipeline by that time. They managed to identify the most common non-carbon benefits of CDM projects, but were unable to quantify how large those benefits were due to the qualitative nature of the method. In contrast, Sutter (2003) introduced a MCA method, namely MATA-CDM, based on Multi-Attribute Utility Theory to quantitatively evaluate the contribution of CDM projects to sustainable development. Sutter & Parreño (2007) later applied the MATA-CDM method to 16 registered CDM projects, but only three non-carbon criteria were used to represent sustainable
development, namely employment generation, distribution of CERs and improvement in local air quality. In another study using the MATA-CDM method, Heuberger et al. (2007) extended the scope of sustainability to 12 criteria for three South African projects and 17 criteria for one Uruguayan project. However, those authors concluded that the MATA-CDM method failed to make a satisfactory quantitative sustainable development assessment of CDM projects and that a stakeholder participation is valuable for sustainable development and should be involved in CDM assessment. By comparing the approval process in six host countries, Disch (2010) also suggests that an on-site visit engaging local stakeholders is more promising in ensuring sustainable development than traditional checklist evaluations. In general, checklist and MCA are the most commonly used methods for sustainable development assessment of CDM projects. However, they are of a qualitative or semi-quantitative nature and thus limited in e.g. making a choice between different combinations of development and environmental policies (Heuberger et al., 2007; Olsen, 2007; Olsen and Fenhann, 2008). A common finding in these studies is that there is a trade-off between the two aims of CDM, i.e. CDM projects tend to favour the cost-effectiveness of CERs and to neglect sustainable development when decisions are left to market forces (Kolshus et al., 2001; Olsen, 2007; Paulsson, 2009; Sutter and Parreño, 2007).

A quantitative approach to measure sustainability is to assess the co-impacts, or ‘ancillary impacts’, which refers to various economic, environmental and social impacts apart from GHG reduction, simultaneously caused by climate change mitigation activities (Aunan et al., 2006; Aunan et al., 2004; Cao et al., 2008; Disch, 2010; Haines et al., 2006; Vennemo et al., 2006). For about 20 years, many studies have tried to quantify the co-benefits of climate change mitigation policies and activities using the CBA method, in which the effects associated with air quality and resulting values for public health are the most important part (Ayres and Walter, 1991; Jack and Kinney, 2010; Mirasgedis and Diakoulaki, 1997). A review of early CBAs of co-benefits since the 1980s can be found in Ekins (1996), who suggested that the co-benefits from abating SO₂ alone could substantially offset the costs of carbon tax. In addition, he claimed that there had been relatively few calculations of co-benefits at that time and that comparison between different studies was difficult because of differences in data sources, treatments and approaches (Ekins, 1996). Since 2000, the number of studies on the co-benefits of climate change mitigation activities has been steadily increasing, and systematic reviews of those studies can be found in e.g. Aunan et al. (2006), Bell et al. (2008) and Nemet (2010). The typical method adopted in co-benefit studies is a combination of an exposure-response model of health-related endpoints with a valuation of the endpoints, which include mortality, hospital visits and a number of respiratory symptoms resulting from air pollutants such as SO₂, PM and NOₓ. The results of those studies usually show that the amount of co-benefits is significantly large and could greatly compensate for the costs of climate change mitigation activities. In addition, the estimated co-benefits in developing countries are often larger than in developed countries. With a specific focus on CDM projects, Vennemo et al. (2006) calculated the average coefficients for China’s energy-related CDM projects, namely how much PM and SO₂ would be simultaneously reduced when one tonne of CER is generated. Their approach provides an effective way of comprehensively assessing the co-benefits of a large number of CDM projects, while the heterogeneity of projects in different categories or regions is not considered. Rive & Aunan (2010) improved this by calculating the coefficients for every project category in every region, and their method is more practical and useful for a profound analysis of CDM projects. Measuring co-impacts represents
an explicit way of unveiling sustainable development, although co-impacts often just cover an incomplete scope (Aunan et al., 2006; Aunan et al., 2004; Cao et al., 2008; Vennemo et al., 2006). A common point of co-benefit studies is that the evaluation cannot be applied to non-energy-related projects, such as HFC23 decomposition projects, since no electricity generation or energy conservation is produced by these projects and hence no air pollutant reductions and related co-benefits can be expected. People will perhaps have to accept the fact that not all projects can provide co-benefits (for further discussion about this method see Paper II).

5.2 Co-benefits of CDM projects
This section examines the co-benefits of China’s CDM projects and the policy implications of these co-benefits. The methods for evaluating co-benefits are discussed first, on the basis of a review of existing studies about China. The co-benefits of Chinese CDM projects are then calculated, including reductions in SO$_2$, PM and NO$_X$ and related avoided deaths and crop losses.

5.2.1 Method for assessing co-benefits
A total of 14 studies on the co-benefits of China’s climate change mitigation activities were reviewed in this study, while many more studies are available for in industrialised countries (for details see Paper II). Based on these studies, a generalised conceptual model for assessing co-benefits was shown in Figure 5-1.

![Figure 5-1 Conceptual model for assessing the co-benefits of climate change mitigation activities](image)

For concrete mitigation projects, such as CDM, a bottom-up approach is more suitable for estimating the reduction in air pollutants, since technical details and site-specific situations can be specifically considered. The next step is to estimate the physical amount of co-impacts corresponding to the reduction in air pollutants, and pollutant dispersion models and exposure-response functions are often used in this process (Figure 5-1). Given the research efforts in the last 20 years, the current knowledge available for quantifying health-related co-benefits is
adequate and appropriate for comparing various energy-related climate change mitigation activities (Bell et al., 2008). The final step is to value the co-impacts and calculate the total values of categories of co-benefits. The largest proportion comes from the avoidance of mortality, although valuation of lives is highly controversial (Bell et al., 2008; Campbell-Lendrum and Corvalán, 2007; Mirasgedis and Diakoulaki, 1997).

However, this detailed method is not effective when the focus switches from a single project to a large number of projects, as in the case of a comprehensive CDM assessment. To solve this problem, Vennemo et al. (2006) calculated the average pollutant coefficients for China’s CDM projects, namely how much PM and SO₂ would be simultaneously reduced when one tonne of CER is achieved. Their approach provides an effective way to comprehensively assess the co-benefits of a large number of CDM projects, while the heterogeneity of projects in different categories or regions is not considered. Rive and Aunan (2010) improved this method by calculating coefficients for every project category in every region, being useful for a more profound analysis of CDM projects (see also Section 5.1 and Paper II).

5.2.2 Co-benefits of China’s CDM projects

China’s CDM projects, primarily in the cooperation with Sweden, were studied to investigate the stringency of the co-benefits assessment. The method for comprehensive assessments was used, more specifically taking coefficients for various types of pollutants, avoided deaths and avoided crop losses from Rive and Aunan (2010), while following the suggestion by Vennemo et al. (2006) to not monetarise people’s lives.

At the end of 2010, there were 153 China’s CDM projects concerning Swedish investment. These projects covered eight types of activities, namely biogas recovery, biomass, coal mine methane recovery, HFC23 decomposition, hydropower, natural gas, energy efficiency-own generation (EE own generation) and wind power. Table 5-1 and 5-2 show the details of these 153 CDM projects regarding project categories and locations. The whole mainland China is divided into seven regions according to the national grid distribution.

Table 5-1 CDM projects in the cooperation between China and Sweden by the end of 2010

<table>
<thead>
<tr>
<th>Region</th>
<th>Biomass</th>
<th>Coal Mine Methane Recovery</th>
<th>HFC23 Decomposition</th>
<th>Hydropower</th>
<th>Natural Gas</th>
<th>EE Own Generation</th>
<th>Biogas Recovery</th>
<th>Wind Power</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td></td>
<td></td>
<td>52</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>1</td>
<td></td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hainan</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>1</td>
<td></td>
<td></td>
<td>5</td>
<td>1</td>
<td>9</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North East</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>North West</td>
<td>12</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td>7</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>105</td>
<td>1</td>
<td>16</td>
<td>1</td>
<td>26</td>
<td>153</td>
</tr>
</tbody>
</table>

Table 5-2 CERs produced by CDM projects in the cooperation between China and Sweden by the end of 2010

<table>
<thead>
<tr>
<th>Region</th>
<th>Biomass</th>
<th>Coal Mine Methane Recovery</th>
<th>HFC23 Decomposition</th>
<th>Hydropower</th>
<th>Natural Gas</th>
<th>EE Own Generation</th>
<th>Biogas Recovery</th>
<th>Wind Power</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>462561</td>
<td>658165</td>
<td>103853</td>
<td>1411821</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>123055</td>
<td>76318</td>
<td>93274</td>
<td>588865</td>
<td>1973019</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hainan</td>
<td>90323</td>
<td>90323</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>3016714</td>
<td>1337948</td>
<td>66393</td>
<td>5997021</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North East</td>
<td>126101</td>
<td>1439958</td>
<td>1566059</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North West</td>
<td>1744596</td>
<td>678289</td>
<td>2583764</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>2243430</td>
<td>2243430</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total CERs</td>
<td>123055</td>
<td>3016714</td>
<td>18848681</td>
<td>8814006</td>
<td>858165</td>
<td>2215056</td>
<td>66393</td>
<td>4386931</td>
<td>38329001</td>
</tr>
</tbody>
</table>


Figure 5-2 (a-e) shows the co-benefits produced by the 153 CDM projects in the cooperation between China and Sweden. Specifically, the co-benefits considered in this study included reduction in SO$_2$, PM, NO$_x$, avoided deaths and crop losses. The results are presented by project category and by region.

By project category

Unit: tonne

By region

Unit: tonne
Figure 5-2 (b) Annual co-benefits of Chinese CDM projects in the cooperation with Sweden – reduction in PM

By project category

Coal Mine Methane Recovery; 844.68

Biomass; 121.82

Wind Power; 780.20

Biogas Recovery; 33.89

EE own generation; 3563.24

Hydropower; 11405.93

Natural Gas; 128.72

By region

North West; 3132.69

North East; 3288.72

North; 6147.39

South; 2467.77

Central; 7599.32

Hainan; 99.36

East; 1165.01

Unit: tonne

Figure 5-2 (c) Annual co-benefits of Chinese CDM projects in the cooperation with Sweden – reduction in NOₓ

By project category

Coal Mine Methane Recovery; 12.07

Biogas Recovery; 0.46

EE own generation; 46.69

Hydropower; 155.08

Natural Gas; 72.09

By region

North West; 38.92

North East; 40.72

North; 75.54

South; 31.41

Central; 180.48

Hainan; 0.99

East; 27.05

Unit: lives

Figure 5-2 (d) Annual co-benefits of Chinese CDM projects in the cooperation with Sweden – avoided deaths from the reduction in PM

By project category

Coal Mine Methane Recovery; 21.12

Biogas Recovery; 0.86

EE own generation; 90.23

Hydropower; 292.53

Natural Gas; 3.43

By region

North West; 83.32

North East; 86.53

North; 156.73

South; 60.57

Central; 194.92

Hainan; 2.62

East; 30.13

Unit: million RMB

Figure 5-2 (e) Annual co-benefits of Chinese CDM projects in the cooperation with Sweden – avoided crop losses from the reduction in NOₓ

Source: UNFCCC, (2011b). CDM Project Database. http://cdm.unfccc.int/Projects/projsearch,

Note: Rive and Aunan (2010) used the exchange rate in 2005 to calculate the coefficients for co-benefits, so the values for co-benefits above may be overestimated compared with current terms.

By implementing the 153 CDM projects in China, a great amount of co-benefits apart from CERs were simultaneously generated. These co-benefits included:

- A 92796.80 tonnes reduction in SO$_2$
- A 6191.11 tonnes reduction in PM
- A 23900.26 tonnes reduction in NO$_X$
- 395 avoided deaths
- 641.44 million RMB avoided crop losses.

Looking more closely at the results, hydropower and wind power projects are the two largest categories in terms of producing co-benefits, and the Central and North regions are the two largest regions in China as regards benefiting from the co-benefits of CDM projects (Figure 5-2). This is because the amount of co-benefits is proportional to the amount of power that would otherwise be produced in the BAU situation, and the amount of power produced by a CDM project is in turn related to its capacity for CER generation (cf. Table 5-1). In addition, there were several other findings and concerns in the study as discussed below.

- Uncertainties were involved in the above assessment, which can be generally divided into measurement of CERs and calculation of coefficients for various co-benefits. For measurement of CERs, PDDs are the best choice of data sources. Calculation of coefficients is complicated and relies on a number of interrelated techniques (Figure 5-1). Accurate application of these techniques calls for knowledge in several fields, such as energy engineering, geology, epidemiology, statistics and environmental economics. This study took the outcomes of previous studies and assumed that the uncertainties involved in the outcomes had been considered.

- Within the eight categories of CDM projects, the evaluation can be applied to the seven categories of energy-related projects and not to HFC23 decomposition projects (Rive and Aunan, 2010). This may be one reason for the criticisms of HFC23 decomposition projects as regards sustainability.

- The regional distribution of co-benefits is uneven, reflecting the uneven distribution of CDM projects (Table 5-1). However, the development of CDM projects depends on a number of complicated issues, e.g. natural environmental resources, local industries, infrastructure and institutional capacity. For instance, over 80% (88/105) of hydropower projects are located in the Central and South regions of China, where there is an abundant amount of water resources; and wind power projects are mostly found in the northern regions (23/26).

**5.2.3 Implications of co-benefit assessment**

The policy implications of co-benefit assessment are discussed here from three aspects: (1) Should co-benefits be included in the current international climate change mitigation negotiations regarding CDM? (2) Should co-benefits be used to ensure the contribution of CDM projects to
sustainable development? and (3) What possible policy implications arise from different co-benefits?

Some previous studies have suggested that co-benefits could be incorporated to justify the huge costs of climate change mitigation activities (Ekins, 1996; Mestl et al., 2005; Pittel and Rübbelke, 2008; Plambeck et al., 1997). However, the evidence presented in this thesis suggests that there is insufficient reason to involve co-benefits at present. If co-benefits were to be taken into account, reduction activities in industrialised countries would also generate co-benefits, and the costs of reductions would be offset by the co-benefits. Hence, the industrialised country would have to re-consider whether it is worth purchasing reduction credits and developing countries would have to re-consider the amount of reduction credits they could offer at a lower price than the net costs of domestic reductions of the industrialised countries. Moreover, different countries would define the scope of co-impacts based on their own needs, and this may cause the values of co-impacts to be manipulated. For example, if China tries to address climate change in order to avoid crop losses, Sweden could argue that its crop yields will be higher due to global warming. In this case, the gain for one country is the loss for the other, and thus the same kind of value is not comparable in different countries. Even if the scope of co-benefits were to be confined to air pollutants and various health-related impacts, all changes would have to be mixed and absorbed on the global market, calling for a consistent pricing basis. Such changes would most likely threaten the current international cooperative system (Nemet et al., 2010; Pittel and Rübbelke, 2008).

Another consideration is that there has been an argument on whether co-benefits should be used to assess the contribution of CDM projects to sustainable development (Aunan et al., 2006). Sustainable development is intrinsically a multi-dimensional concept and has different meanings in different contexts. Current studies on co-benefits mainly consider changes in air pollutants and associated health-related and other quantifiable impacts, while many other important issues regarding sustainable development, such as technology transfer, employment generation and poverty alleviation, are difficult to quantify and have scarcely been involved (Olsen, 2007; Sirohi, 2007; Sutter and Parreño, 2007). In addition, co-benefits may also create misleading information if the values are used alone to ensure CDM’s contribution to sustainable development. Given that a project’s co-benefits are related to the amount of CERs it produces (see the assessment above), for the same category of projects in the same region, the conclusion is that the more CERs a project can produce, the greater its contribution to sustainable development. Obviously, this is a debatable verdict. Since sustainable development represents a much more comprehensive concept than co-benefits, it is inappropriate to use co-benefits alone to assess CDM’s contribution to sustainable development.

What policy implications arise from assessing different co-benefits? In China, the policy focus is often on acidification and other environmental problems resulting from pollutants such SO₂, NOₓ and PM, rather than climate change, and this was also the main issue in Sweden 30 years ago. Actions aimed at reducing air pollutants can also achieve GHG reductions as co-benefits in many cases (Gielen and Changhong, 2001; Morgenstern et al., 2004). Given the possibility to achieve double targets through the same effort, decision-making would benefit from co-benefit assessments that can indicate synergies or optimised trade-offs between climate change mitigation and protecting local environment (Campbell-Lendrum and Corvalán, 2007). In particular for local
governments, which do not always have sufficient budgets on multiple environmental actions, the development of CDM projects is one way to achieve both policy concerns. For example, China’s energy-related CDM projects, e.g. hydropower and wind power, are important not only for reducing GHG emissions, but also for abating air pollutants and delivering other co-benefits (Figure 5-2). Therefore, these projects should be further encouraged to help China address climate change and improve the ambient environment.

5.3 Experimental study using AHP

Under the MCA umbrella there are many techniques, such as weighted averages, analytic hierarchy process (AHP), priority setting, outranking, fuzzy integrals and various combinations of different techniques. At present, AHP is the most popular technique to assist in decision-making (Kiker et al., 2005; Pohekar and Ramachandran, 2004). The AHP method was first developed by Saaty (1977) and is a theory of measurement through pairwise comparisons, which rely on the judgement of stakeholders to represent how much one element dominates over another with respect to a given impact (Saaty, 1980; 1990; 2005). By arranging impacts in a hierarchic structure, the AHP method may be especially appropriate for comparing a limited number of projects with respect to dimensions of impacts on sustainable development, mixing both qualitative and quantitative information (Ramanathan, 1999; 2001; Vaidya and Kumar, 2006). This section compares a hydropower project with a HFC23 decomposition project in terms of sustainability using the AHP method. Pros and cons of the AHP method in terms of sustainable development assessment of CDM projects are discussed.

5.3.1 Principle of the AHP method

![Figure 5-3 The AHP structure adopted in this study](image)

A detailed description of the AHP method can be found for example in Saaty (1980; 1990; 2008), Ramanathan (1999; 2001) and Berrittel et al. (2008). Figure 5-3 shows the AHP decision model adopted in this study. The first level of the model is the overall goal of the assessment, namely to
compare the sustainability of two CDM projects. On the second level, there are four dimensions of criteria, against which the two alternative projects on the bottom level are assessed. Due to the complexity and debate on defining the scope of sustainable development (Hugé et al., 2009; Munda, 2005), peer-reviewed studies on CDM projects were scrutinised and concerns about the sustainability of CDM projects and other climate change mitigation actions were collated into the criteria of environmental, social, economic and others, as seen in Figure 5-3. Searches were made of a number of renowned scientific journals using keywords such as CDM, climate change and sustainable development (for details see Paper V). A hydropower project (ref. 2255) and a HFC23 decomposition project (ref. 0304) were selected as the two alternatives for comparison (these two projects were the newest entries in their categories when the experimental workshop was prepared). Their PDDs were the major information sources.

In order to decide the weightings on the four criteria and on the sub-criteria below them, a fundamental scale of numbers was adopted for making comparisons (Table 5-3). The scale of numbers indicates the relative importance of one element compared with another with respect to a certain property (Saaty, 1980; 1990; 2008).

**Table 5-3 Fundamental scale of numbers used in the study**

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>2</td>
<td>Slight plus</td>
<td>Intermediate values between 1 and 3</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance of one over another</td>
<td>Experience and judgement slightly favour one activity over another</td>
</tr>
<tr>
<td>4</td>
<td>Moderate plus</td>
<td>Intermediate values between 3 and 5</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Experience and judgement strongly favour one activity over another</td>
</tr>
<tr>
<td>6</td>
<td>Strong plus</td>
<td>Intermediate values between 5 and 7</td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated importance</td>
<td>An activity is favoured very strongly over another; its dominance demonstrated in practice</td>
</tr>
<tr>
<td>8</td>
<td>Very, very strong</td>
<td>Intermediate values between 7 and 9</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>The evidence favouring one activity over another is of the highest possible order of affirmation</td>
</tr>
</tbody>
</table>

Reciprocals of above
If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i

A reasonable assumption

RI is the average consistency of 500 randomly generated matrices (for details see Paper V); CI refers to the consistency index of the matrix; and, for a matrix of order n, CI is defined as:

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1}$$

where $\lambda_{\text{max}}$ is the maximum eigenvalue of the matrix. When CR is not greater than 0.1, the consistency is considered tolerable.
5.3.2 Design of the experimental workshop
To derive weightings on various criteria and assess the two projects, an experimental workshop was organised in October 2009 in the course Ecological Economics (course number MJ2694), which is compulsory in the international Master’s Programme in Sustainable Technology at the Royal Institute of Technology, Sweden. Ecological Economics is one of the advanced courses given in the last period of the programme (Industrial Ecology, 2009). This means that all the students participating in the workshop had been trained in terms of a deep and holistic understanding about sustainable development, and that many students also had experience in analysing various types of climate change mitigation activities, including CDM projects.

The workshop was attended by 45 students from more than 10 countries, including industrialised and developing countries, and they were randomly allocated into two groups. It should be noted that there was a large difference in age between the students, and some of them had many years of practical experience. Generally speaking, the students represented a variety of interests, which is important for AHP application (Vaidya and Kumar, 2006). Both groups (referred to as group A and B) submitted their judgement matrices after the workshop on the basis of group discussion, and the consistency of all matrices met the AHP requirement.

5.3.3 Results and implications
Tables 5-4 and 5-5 show the results from Group A and B, respectively.

| Table 5-4 Final verdict of Group A on the two CDM projects with respect to sustainable development |
|---|---|---|---|---|---|
| | Goal: Sustainable development | D1: Environment | D2: Society | D3: Economy | D4: Others |
| Weighting | 1 | 0.57 | 0.27 | 0.04 | 0.13 |
| Project 0304 | 0.58 | 0.71 | 0.38 | 0.46 | 0.48 |
| Project 2255 | 0.42 | 0.29 | 0.62 | 0.54 | 0.53 |

| Table 5-5 Final verdict of Group B on the two CDM projects with respect to sustainable development |
|---|---|---|---|---|---|
| | Goal: Sustainable development | D1: Environment | D2: Society | D3: Economy | D4: Others |
| Weighting | 1 | 0.38 | 0.38 | 0.18 | 0.06 |
| Project 0304 | 0.57 | 0.54 | 0.68 | 0.35 | 0.65 |
| Project 2255 | 0.43 | 0.46 | 0.32 | 0.65 | 0.35 |

Generally speaking, Group A concluded that the HFC23 decomposition project performed slightly better than the hydropower project. The reason was that the HFC23 decomposition project gained a much higher score on the environmental criterion than the hydropower project, although its scores in the other three criteria were lower (Table 5-4). Group B also considered that the HFC23 decomposition project can make a larger contribution to sustainable development and it exceeded the hydropower project for environmental, social and other criteria, while just falling behind for the economic criterion (Table 5-5). Interestingly, the results contradict the arguments against HFC23 decomposition projects as making significantly less contribution to SD in developing countries than renewable energy projects (Olsen, 2007). This indicates the weakness of current research on CDM’s sustainability, including: (1) The adherence to existing methods such as MATA-CDM and CBA of co-impacts, which mainly focus on energy-related benefits of CDM project activities (Disch, 2010); and (2) the focus on direct benefits, while the indirect benefits are often neglected, i.e. the spread-over effects of CER.
revenues, technology and infrastructure development about climate change, capacity building and human resource development regarding various mitigation activities, and increased public awareness of climate change issues in developing countries (Fenhann and Staun, 2010; Lecocq and Ambrosi, 2007; Liverman, 2009).

Looking back through the assessment, the whole analysis largely remained transparent. This is an important feature that guarantees the quality of an assessment, especially when subjectiveness is unavoidable (Heuberger et al., 2007; Saaty, 2008). The majority of values in an AHP heavily depend on the participants’ judgements, which unavoidably involve their personal feelings and interests. As noted, the results from this experimental study were based on students’ opinions, and would very much likely have been different if the participants had been real stakeholders and decision-makers, such as CDM experts, project owners and local citizens (Sun et al., 2007). Real stakeholders usually present individual preferences regarding part of sustainable development, rather than making their judgements from a holistic perspective. In contrast, the students participating in this study represented more comprehensive concerns about sustainable development than real stakeholders, while they did not have much practical experience in operating and managing CDM project activities. Therefore, it would be interesting to carry out another study with real CDM stakeholders and decision-makers in the next step and compare the results from different participants.

In general, the AHP method is very useful for decision-making, especially in a complex situation relating to sustainable development, where large amounts of qualitative and quantitative information are mixed together. The AHP method is effective in breaking down a complex problem into small sub-problems, which can be solved easily, and formulating them into a systematic structure following people’s thinking route (Ramanathan, 2001; Saaty, 2005). However, some weaknesses of the AHP method were also identified in this study. These included: (1) The breaking-down and weighting of criteria can be very subjective, even arbitrary. This study dealt with the problem by referring to a review of existing studies and leaving the process transparent. (2) The final results depend heavily on the participants, and achieving agreement among all participants is not always easy; (3) There must be a limited number of alternatives to be assessed in one study, since it would otherwise be very difficult to perform the assessment; and (4) The final results that are presented in subjective values are difficult to be reused elsewhere, partly due to the problem of rank reversal (Wang and Elhag, 2006), or in comprehensive assessments on how much contribution CDM projects would produce.

5.4 Short summary

There is more debate on whether CDM projects contribute to sustainable development in developing countries than on the other aim about cost-effectiveness, partly because of the complexity regarding sustainable development. Researchers have long been trying to evaluate CDM’s contributions to sustainable development, mainly using checklist, MCA and CBA. However, none of these methods is capable of providing completely satisfactory results. Comparatively speaking, co-benefit assessment is better in terms of providing quantitative results than MCA, while restricting the scope of sustainable development to measurable impacts as a trade-off. While a particular MCA method, namely MATA-CDM, is one of the most popular methods for addressing a comprehensive scope of sustainable development, it cannot determine how much a concrete project can contribute to sustainable development, i.e. the method does
not provide quantitative measurements. Therefore, a bottom-up approach through engaging local stakeholders in CDM design and approval, combining mandatory monitoring and evaluation of co-benefits, could be a more effective option for safeguarding development benefits than any global standards, which are often proposed, and may be easier to implement.

The co-benefits of China’s CDM projects were studied here, using the method adapted for comprehensive analyses of CDM. It was found that energy-related projects are able to produce a significant amount of co-benefits, while HFC23 decomposition projects were excluded from the assessment. In a discussion about the policy implications of co-benefits, this study suggested that co-benefits should neither be involved in current international climate change mitigation negotiations, nor used alone to ensure the contribution of CDM projects to sustainable development. However, co-benefits analysis can indicate synergies or optimised trade-offs between climate change mitigation and protecting the local environment, which is valuable for developing countries, especially their local governments.

In the experimental study using the AHP method to compare a hydropower project with a HFC23 decomposition project, the results from both participating groups showed that the HFC23 decomposition project could make a larger contribution to sustainable development, especially in terms of environmental impacts. The AHP method features a system structure that is effective in breaking down a comprehensive problem into pairwise comparisons and involves intensive participation by stakeholders, which is important for local sustainable development. Weaknesses of the AHP method are: (1) break-down and weighting of criteria can be very subjective; (2) the final results depend heavily on the participants in the assessment; (3) only a limited number of alternatives can be considered; and (4) the final results are difficult to use elsewhere.

Existing studies, whatever the method adopted, often claim that there is a trade-off between the dual aims of CDM, especially when it comes to HFC23 decomposition projects. However, this argument mainly concerns the direct impacts made by CDM projects, while the indirect benefits are often neglected. For example, a major part of the revenues (65%) from the CER transfer on HFC and PFC projects will be further invested in other climate change mitigation activities, broadly contributing to local sustainable development.
6 Discussion and Conclusions

Following the ‘common but differentiated’ principle under the Kyoto Protocol, the industrialised countries promised to reduce their domestic GHG emissions, while developing countries had no compulsory responsibilities. However, the reality did not match the plan. In the past few years, industrialised countries have been counting on developing countries to do more about their exponentially increasing emissions, while developing countries are still waiting for industrialised countries to fulfil their mitigation commitments and financial and technological transfer, which they promised nearly two decades ago (Grubb, 2010; Howes, 2009). While there is as yet no specific method capable of dealing with all the scientific and political challenges regarding climate change, the general consensus is that the reductions in GHG emissions needed to avoid catastrophic climate results cannot be attained by any country’s effort alone (Dubash and Rajamani, 2010; Figueres and Streck, 2009). Against this background, CDM has naturally become one of the key approaches since it was launched, because it not only establishes the first legitimate mechanism for carrying out climate change mitigation in a collaborative way between industrialised and developing countries, but also provides a crucial starting point for developing countries to undertake increasingly stringent mitigation targets.

This thesis analysed the dual aims of CDM and specifically focused on China’s CDM projects. In the following, previous work is first revisited to address the aims and objectives of this study. The discussion is then extended to arguments about CDM in order to provide a comprehensive picture. The chapter concludes with suggestions on the future of CDM.

6.1 Revisiting the work done on the dual aims of CDM

- **CDM represents an innovative instrument to achieve climate change mitigation**

CDM has been operating successfully for nearly a decade, and it seems that the concept of CDM has touched the right point of collaborative action under the current international regime of climate change mitigation.

One reason for CDM’s successful implementation is the clear and rigid definition of working flow and the concepts about additionality, although some studies suggest that there is still room to increase the efficiency in the current design (Friberg, 2009; Lotz et al., 2009; Streck and Lin, 2008). For example, the CDM EB mainly consists of experts in international environmental negotiations, rather than market regulation, which is de facto the first priority of the EB (Streck and Lin, 2008). A process of professionalisation of the CDM EB by recruiting full-time professionals is now underway in order to cover the entire range of the EB’s responsibilities. The rule of additionality has a general effect on stimulating the processing of candidate projects, although there is a debate between researchers and practitioners on how strictly additionality should be defined (Figueres and Streck, 2009).

Another reason for the successful implementation of CDM is its strong theoretical foundations. From an emission trading perspective, CDM for the first time enables broad participation in an emission trading scheme and encourages a ‘win-win’ situation between participants, although neither the concept nor the practice of emission trading is completely new. From a commons perspective, the exercises of CDM in recent years have provided valuable knowledge for
governing climate change mitigation activities in terms of collaborative actions between stakeholders at different levels and across multiple scales. Even though a certain form of institution design for governing climate change mitigation is still unknown, the way of co-management indicates a highly viable solution at present.

- **CDM has a double mitigation effect, in both the Annex I countries and developing countries, without double counting**

As regards its aim of cost-effectiveness, CDM in general has been able to provide a substantial amount of CERs at attractive prices, i.e. the total amount of China’s CERs alone had reached 52.70% of the entire mitigation commitments of industrialised countries according to the Kyoto Protocol by the end of 2010. The number was over twice the domestic reduction efforts of the industrialised countries and can be larger if the entire CDM system in all developing countries is considered. This result provides strong empirical evidence in support of CDM’s contribution to current reduction compliance with the Kyoto Protocol, and it is even beyond the expectations of most experts (Friberg, 2009). However, there is much less discussion about the potential of CDM on the demand side, which can also significantly affect the overall size of global CDM transactions (Heggelund, 2007; Jotzo and Michaelowa, 2002). For example, the USA’s CO₂ emissions in 2008 exceeded its Kyoto target level by more than 1240 million tonnes (IEA, 2010), and thus the demand for CO₂ on the carbon market would have been greatly increased if the USA had undertaken its responsibility.

In addition, this thesis found that CDM projects help developing countries lower their emission trajectories, especially in the long run, and that this effect does not conflict with the CERs accredited to the Annex I countries. Due to the dominance of fossil fuels, the contribution of CDM projects to limiting China’s total emissions is small, while CDM’s role in stimulating renewable energy is significant, e.g. about 11% of hydropower and 93% of wind power were generated by CDM projects in 2010.

China is currently the most active and attractive country for CDM projects worldwide, although it was initially sceptical about the mechanism (Heggelund, 2007). Given that CDM is very likely to continue after 2012, it will significantly help China improve its energy structure in the long run (Fenhann, 2011; Figueres and Streck, 2009).

- **MCA or CBA alone cannot assess sustainable development in a completely satisfactory way**

This thesis reviewed popular methods such as checklist, CBA and MCA, carried out a CBA of the co-benefits of China’s CDM projects, and adopted the AHP method in an experimental study comparing two CDM projects. Every method has its own advantages and problems at the same time; or in other words, neither the CBA of co-benefit assessment nor the popular MCA method such as AHP alone is able to assess sustainable development in a completely satisfactory way. Currently, a bottom-up approach through engaging local stakeholders in CDM design and approval, combining mandatory monitoring and evaluation of co-benefits, could be more effective for safeguarding local sustainable development than any consolidated standards.

In practice, the UNFCCC secretariat has started to gather information on the co-benefits of CDM projects. Typical projects have been identified so far as e.g. making a unique contribution
to local employment, freeing up financial resources for households and making other essential services available (UNFCCC, 2011a). This effort, in the long run, is likely to greatly assist the evaluation of CDM’s impacts on sustainable development, and help to examine the arguments.

In addition, this thesis identified some limitations in existing studies. Firstly, most studies focus on the so-called direct impacts alone and ignore indirect benefits such as the spread-over effects of CER revenues, technology and infrastructure development about climate change, capacity building and human resource development regarding various mitigation activities, and increased public awareness of climate change issues in developing countries. Secondly, most criticisms of CDM are actually based on examinations of individual projects, rather than comprehensive analyses and mainly focus on HFC23 decomposition projects, rather than various types of CDM projects. However, Seres (2007) and Nussbaumer (2009) suggested that technology transfer mainly occurs in HFC23 decomposition and thermal efficiency projects.

From a methodology point of view, the challenges in defining a comprehensive scope of sustainable development and in choosing an appropriate method to examine CDM projects have given rise to much debate on the role of CDM in developing countries. Since it is much easier to define an unsustainable impact than a sustainable one, it may help to stop the arguments on sustainable development by looking at the negative side of CDM projects in developing countries. No single CDM project has failed to gain approval due to lack of contribution to sustainable development (Friberg, 2009), and this means that CDM projects, at the very least, do not hamper local sustainable development in developing countries. Given this fact, it is perhaps time to switch the focus from whether or not CDM projects assist in sustainable development to how developing countries could make better use of CDM projects, as well as using direct and indirect benefits to promote local development.

6.2 Other concerns about CDM

Apart from the dual aims, there are other concerns about CDM, some of which are addressed in the previous chapters. This section summarises these issues, and hopefully provides a holistic understanding of CDM.

- Distribution of CDM projects in the world

The equitable regional and sub-regional distribution of CDM activities has long been a significant concern of various parties. Figure 3-2 in this thesis shows the current distribution of CDM projects in the world, with a few large developing countries, i.e. China, India and Brazil, holding dominant shares. In order to encourage CDM in the least developed regions, the CDM EB remains committed to addressing relevant barriers and the UNFCCC secretariat continues to support capacity-building initiatives in these places (UNFCCC, 2010a). However, only a few African countries so far have successfully developed CDM projects. This is because the mitigation potential of a country is fundamentally decided by its emissions, as well as being affected by the related institutional capacity and general investment environment (Jung, 2006). Those least developed countries do not have any significant emissions at present, and as a result the reduction potential that could be further developed into CDM credits is naturally limited. In conclusion, it would be very positive if more CDM projects were constructed in the least developed countries and assisted in their sustainable development, but it is not practical to expect
an absolutely equitable distribution worldwide, and ridiculous to allocate any mitigation tasks to the least developed countries.

- **Transaction costs for CDM projects**

The validity of CDM projects is ensured by the rigorous public registration process, including PDD preparation and approval, project monitoring and verification, which represents the major source of transaction costs. These costs can be substantial and may affect project profitability or even viability, especially for small-scale projects (Chadwick, 2006; Michaelowa and Jotzo, 2005). A series of measures have been taken by the CDM EB with the aim of reducing the transaction costs and shortening project processing times, such as: streamlining the approval process, recruiting the secretariat team, and simplifying the demonstration of additionality and the establishment of emission baseline scenarios (UNFCCC, 2010a). In addition, as more experience of project administration has been gathered, the average costs per project have tended to decrease over time. Nevertheless, transaction costs will never be reduced to zero, and all costs will be finally added to CDM projects. There is always a need to keep the costs as low as possible, without sacrificing the stringency in project registration.

- **The problems of ‘running to the bottom’ and ‘low-hanging fruit’**

Another concern is about the low-cost mitigation potential in developing countries, which can be referred to as the problems of ‘running to the bottom’ and ‘low hanging fruit’ (IPCC, 2007). The problem of ‘running to the bottom’ was raised due to worries about the hypothetical situation where developing countries compete with each other for limited CDM investment by reducing their CER prices (Sutter, 2003). This would not only break the entire CDM system, but also severely harm the developing countries in many ways. However, as China and many other countries started to set up a floor price for CER credits, these worries have been relieved. The so-called ‘low-hanging fruit’ problem refers to the situation that developing countries may find themselves worse off in the future when they start to undertake mitigation compliance of their own, since all cheap potentials will have been explored already. However, both conceptual modelling and empirical studies show that the ‘low-hanging fruit’ argument is weak, and even in China, current CDM projects have reaped only 30% of theoretical CDM potential (Castro, 2010; Narain and van’t Veld, 2008). With respect to CDM potential, those countries that heavily rely on coal, e.g. China and India, tend to have much larger reduction potentials of CDM than those countries where hydropower is the predominant energy source, e.g. Brazil and many other Latin American countries (Friberg, 2009; Jotzo and Michaelowa, 2002).

### 6.3 Looking ahead

The CDM system is not perfect, but it has been significantly improved over time. One current development direction for CDM is to scale-up the mitigation activities by involving programmatic CDM or policy CDM (pCDM) projects. The pCDM activities by design aim to simultaneously involve an unlimited number of similar mitigation projects, which are usually small-scale activities that would be too expensive to establish as regular CDM projects. By the end of 2010, been over 70 pCDM projects had been registered in the database, almost 40% of which were located in Africa and Latin America (Fenhann, 2011). Since the threshold to develop a CDM project is significantly reduced in pCDM, it is expected that pCDM projects would be
more equally distributed around the world and would represent more extensive efforts in promoting sustainable development, especially in the least developed areas (Fenhann and Staun, 2010; Figueres and Streck, 2009; Friberg, 2009).

Nevertheless, CDM is not the universal panacea for healing climate change and cannot be expected to thoroughly change the emission profiles in developing countries. A pertinent evaluation of CDM should concentrate on whether the dual aims have been met, while over-cynical criticisms will do no good. CDM has successfully involved the industrialised countries, the developing world, government agencies, non-governmental organisations (NGOs) and private sectors, and has created unprecedented collaborations for climate change mitigation between these. For most developing countries, CDM serves as the meaningful start of an ambitious mitigation strategy and a low-carbon energy system in the long run. In addition, the cheap CERs are the major source of low-cost reduction credits on the global carbon market. Without CDM, the mitigation costs would dramatically increase and this might cause unaffordable consequences for the global climate regime. However, the future of CDM is still unclear, mainly due to the uncertainties about the mitigation commitments in the post-2012 regime. The conclusion of this thesis is that there is more than sufficient reason for CDM to continue in the post-2012 regime. For developing countries, learning from CDM projects and applying the lessons to their domestic development agenda is more valuable than gaining CER revenues alone. CDM can be an important starting point for developing countries to gradually adopt incremental GHG reduction and limitation targets.
7 References


Understanding the Clean Development Mechanism and its dual aims

Qie Sun, Industrial Ecology, KTH, 2011


Seres, S., 2007. Analysis of Technology Transfer in CDM Projects - prepared for the UNFCCC Registration & Issuance Unit CDM/SDM. Climate Change Economist, Montreal, Canada.


UNFCCC, 2010a. Annual report of the Executive Board of the clean development mechanism to the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol. UNFCCC, Cancun, 3 November 2010. http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5270.php.


