

## *Climate Change Mitigation in Advanced Developing Countries: Empirical Analysis of the Low-hanging Fruit Issue in the Current CDM*

Paula Castro

University of Zurich  
Center for Comparative and International Studies

ISSN 1662-7504



Universität Zürich

**ETH**

Eidgenössische Technische Hochschule Zürich  
Swiss Federal Institute of Technology Zurich

# **Climate change mitigation in advanced developing countries:**

## Empirical analysis of the low-hanging fruit issue in the current CDM

**Paula Castro**

University of Zurich

Institute of Political Science and Center for Comparative and International Studies

castro@pw.uzh.ch

March 2010

### **Abstract**

Under the Kyoto Protocol, developing countries can voluntarily participate in climate change mitigation through the Clean Development Mechanism (CDM), where emission reduction credits from projects in developing countries are bought by industrialized countries to meet their own commitments. Before its implementation, developing-country experts opposed the CDM, arguing that it would sell off their countries' cheapest emission reduction options and force them to invest in more expensive measures to meet their future reduction targets. This paper analyzes this "low-hanging fruit" argument empirically. CDM projects' emissions abatement costs and potentials are estimated for different technologies in eight countries, using capital budgeting tools and the information from the projects' documentation. Through a comparison with theoretical marginal abatement cost curves, we discuss whether the low-hanging fruit argument holds. We find that the CDM is not yet capturing a large portion of the identified abatement potential in most countries. While the costs of most emissions reduction opportunities grasped lie below the average credit price, there is still plenty of low-cost opportunities available. Mexico and Argentina appear to use the CDM exclusively for harvesting the low-hanging fruit, whereas in the other countries analyzed more expensive projects are also accessing the CDM. This evidence challenges the low-hanging fruit claim.

**Key words:** Climate change, Kyoto Protocol, Clean Development Mechanism (CDM), Abatement costs, Low-hanging fruit problem

## 1. Introduction

Under the framework of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, developing countries have no binding targets for greenhouse gas emission reductions up to 2012. They can however voluntarily participate in climate change mitigation through the Clean Development Mechanism (CDM), one of the Kyoto Protocol's flexibility instruments. Under the CDM, emission reduction credits (so-called Certified Emission Reductions or CERs) from projects in developing countries are bought by industrialized countries<sup>1</sup>, which can use them to meet their own reduction commitments. While its main goal is ensuring cost-effectiveness of mitigation measures, the CDM has the second aim to benefit host developing countries by promoting investment in sustainable development and facilitating technology transfer, thereby contributing to their transition to a more climate-friendly economy.

Previous to the full-scale implementation of the CDM, developing-country NGOs and experts opposed this mechanism, arguing that the CDM would imply selling off developing countries' cheap emission reduction options (the "low-hanging fruit") to industrialized countries. This would result in developing countries having to invest in more expensive measures to meet their own reduction targets when they were to commit to these. See Narain and van't Veld (2008) for a review of some occasions when the low-hanging fruit issue has been discussed in the Kyoto negotiations. This low-hanging fruit focus of the CDM has also been criticized more recently from a developed-country perspective, on the grounds that the subsidy granted by the CDM to very large, low-cost CDM projects is disproportionately large as compared to the cost of implementing the emission reductions (Wara, 2006). Despite these concerns and criticism, the CDM has grown successfully even in the countries that were initially most sceptical of it (such as China, see Tangen and Heggelund, 2003 and Bang et al., 2005), and as of October 2009, almost 4700 projects and 2.8 billion tonnes CO<sub>2</sub>eq of emission reductions are expected to be achieved up to 2012 (URC, 2009). For the last three years, monthly project inflows averaged more than 100 and have not been touched by the economic and financial crisis to date.

Now that new international negotiations are taking place with the goal of designing a new climate regime for the period after 2012, these arguments are likely to play an important role on the decisions to be taken. For a new post-2012 climate change agreement, there is considerable pressure that some fast-growing developing countries take up binding emission reduction commitments. Firstly, it is now recognized that

---

<sup>1</sup> In the Kyoto Protocol, those industrialized countries with mandatory emission reduction targets for the period 2008-2012 are listed in Annex B, and thus known as "Annex B countries". Annex B is an update of the UNFCCC's Annex I, which lists the countries that were members of the OECD (Organization for Economic Co-operation and Development) in 1992, plus countries with economies in transition, including the Russian Federation, the Baltic States, and several Central and Eastern European States. Under the Convention, these countries agreed to reduce GHG emissions to 1990 levels by the year 2000. Countries in both lists are the same, except for Belarus and Turkey that do not appear in Annex B. In the following, countries with emission reduction targets will frequently be referred to as "industrialized countries", and countries without targets ("non-Annex B countries") as "developing countries". It should be noted here that this concept of developing countries also includes some rapidly industrializing countries such as China, south-east Asian countries, and oil exporting countries of the Gulf region.

future global emissions reduction targets need to be much more ambitious than the Kyoto target for avoiding dangerous climate change. Secondly, some large and fast-growing developing countries already emit such high levels of GHGs that their participation is regarded as crucial for avoiding dangerous climate change<sup>2</sup> (Bang et al., 2005; Gupta et al., 2007; Höhne et al., 2007; Parry et al., 2007; WRI, 2008). Thirdly, concerns about the impacts of climate policy on a country's competitiveness in the global markets and on the likelihood that energy-intensive industries migrate to countries without emission reduction targets have been prominent in research, as well as in international and domestic policy debates (see e.g. Hourcade et al., 2001; Baumert and Kete, 2002; Cosbey, 2005; Barker et al., 2007; European Commission, 2008). These concerns are leading industrialized countries to increasingly demand advanced developing countries to take up emission reduction commitments.

Developing countries, however, oppose committing to reduction targets. Their main arguments are the historical responsibility of industrialized countries for already existing carbon concentrations in the atmosphere; the negative impact that reduction targets might have on development, poverty alleviation and growth, which would put them in still worse conditions to compete in the globalized markets; and notions of fairness in the amount of emissions a person is allowed to generate in developing countries as compared to industrialized ones. For detailed accounts of different countries' and groupings' positions in the international negotiations towards new climate commitments, see Bang et al. (2005) and, more recently, Höhne et al. (2007) and WRI (2009).

The CDM experience is playing an important role in the climate negotiations as well. Some developing countries and environmental NGOs consider the CDM as a means for industrialized countries to shift their emissions reduction responsibility to other countries. Based on its project-by-project nature, critics argue that it creates disincentives for developing countries' governments to pass climate-friendly legislation<sup>3</sup>. Due to the large financial flows achieved by the CDM, industrialized countries feel uncomfortable that the expectation to continue receiving these funds is a reason itself for advanced developing countries not to take more ambitious climate change mitigation actions. Finally, the costs of mitigation actions, coupled with the above-mentioned fear that the CDM has already captured the cheapest ones, make developing countries even more unwilling to commit.

This paper focuses on this last argument, and intends to test it using empirical data. It thus seeks to contribute to the discussion on the role of offset mechanisms in achieving global GHG emission reductions. So far, as the discussion about the low-hanging fruit issue took place before the CDM was

---

<sup>2</sup> Recent calculations suggest that China is now the largest CO<sub>2</sub> emitter in the world, surpassing even the USA (MNP, 2008). However, per-capita emissions in this and other large developing countries are still very low in the global ranking.

<sup>3</sup> In order to be approved, CDM projects need to demonstrate that they would not have happened without the support from the CDM (additionality rule). Thus, if in country X there is a piece of legislation mandating, for example, the use of energy saving lamps, then this country cannot propose a CDM project for replacing incandescent bulbs with energy saving ones. This rule discourages countries from passing climate-friendly legislation, because they do not want to lose the revenues from possible CDM projects. To avoid this perverse incentive, the CDM authorities created a new rule in November 2005, which states that climate-friendly policies passed after the year 2001 are not to be counted towards the additionality constraint of CDM projects.

fully operational, most of the research on this issue has been theoretical and model-based, and thus no empirically-based evidence of its validity has been presented yet. With the large number of CDM projects in the current portfolio, it is now possible to assess the validity of the low-hanging fruit claim.

Firstly, we review the existing literature on the low-hanging fruit claim and on emissions reduction costs and potentials. Secondly, we detail our approach for testing this claim. We estimate the emissions abatement cost of CDM projects using the financial information provided in their Project Design Documents (PDDs). A dataset of projects, their technologies, estimated costs and expected amount of emission reductions is built for eight CDM host countries and summarized in the form of CDM-specific abatement cost curves. These curves are then compared with existing abatement cost curves and abatement potential estimations from the literature, in order to discuss whether only or mostly the cheapest abatement options are being captured by the CDM in each country. Conclusions for the CDM, the low-hanging fruit argument and its relevance for the ongoing climate negotiations follow.

## **2. Greenhouse gas emissions abatement costs and potentials**

The discussion on the low-hanging fruit issue builds on the concepts of greenhouse gas emissions abatement costs and abatement potentials. Abatement costs describe the costs society has to bear for the reduction of one tonne of CO<sub>2</sub> emissions – or the equivalent amount of other greenhouse gases – by a certain mitigation activity. Abatement costs are important considerations in the design of climate policy, as they determine the cost-effectiveness of individual policy or project choices. Abatement potentials – the volume of emissions reductions that can be achieved by applying a specific technology in a specific region or country in a certain period of time – are equally important, as they determine the amount of mitigation that is feasible. Following Bakker et al. (2007), potentials can be defined as technical abatement potential (reductions that can be realized based on technical and physical parameters), economic potential (reductions that can be realized below a certain cost level) and market potential (reductions that can be realized considering other market barriers). Costs and potentials for different technologies in a country or region are usually displayed together to form a marginal abatement cost curve (MAC).

MAC curves are used extensively in environmental economics to link a firm's (or a country's) pollutant emission levels and the cost of each additional unit of pollution reduction (McKittrick, 1999). Examples of the use of MACs at the firm and at the country level can be found in McKittrick (1999), Ellerman and Decaux (1998) and Criqui et al. (1999). MAC curves for climate mitigation can be derived using a top-down approach by means of macroeconomic (computable general equilibrium) models with a detailed energy sector component. They can also be obtained on the basis of engineering data of emission reduction technologies using a bottom-up approach (Criqui et al., 1999).

Climate-economy models and many studies use these curves systematically (see e.g. Kuik et al., 2008 for a meta-analysis of abatement cost estimates). However, abatement cost estimates are frequently based on expert opinion, or on model assumptions on the climate policy target, the emissions baseline, discounting rates, future technological options, among others. Further, there are only few abatement cost and potential studies focusing on developing countries. Two good examples are the efforts by Wetzelaer et al. (2007) and Bakker et al. (2007) to build an abatement cost curve for these countries in the years 2010 and 2020, respectively. Recently, the consultancy Mc Kinsey has started to develop global and country-specific MAC curves for the year 2030, which have eagerly been taken up in the international climate policy debate (see Enkvist et al. 2007 for an overview). However, as the assumptions and methodology used in the Mc Kinsey curves are not publicly accessible, in this study we opted for using only bottom-up MAC curves and abatement cost and potential estimations with more transparent assumptions that are easier to control for.

### **3. The low-hanging fruit issue in the literature**

The low-hanging fruit issue – also known as the sold-out hypothesis, the cherry-picking or the cream-skimming problem – has been a discussion point already during the negotiations towards the CDM. It claims that developing countries will be worse off after selling their cheapest abatement options (the low-hanging fruits) to industrialized countries through the CDM, because they will have to invest in more expensive options later, when they assume their own emission reduction targets.

#### Possible determinants of the low-hanging fruit issue

Several characteristics of the climate regime give shape to this argument. First, a necessary condition for it to be true is that developing countries, especially the more advanced ones, will eventually “graduate” and commit to own GHG emission reduction targets (Akita, 2003). This is at present one of the most controversial debate topics in the international negotiations towards a post-Kyoto agreement. While Kyoto presupposes such a transition and industrialized countries are trying to push for it, the existing rules do not explicitly include it, and developing countries are – in the majority of cases – against this evolution.

Second, the availability of CDM project options is not only influenced by the cost of the abatement measures, but it is also constrained by financial, technical and institutional barriers in the host countries. Especially the high CDM transaction costs and cumbersome registration procedures may prevent attractive abatement options from accessing the mechanism, particularly if they are small-scale. While this situation is expected to improve with new modalities of CDM projects, probably some of these cheap abatement options will remain available for contribution to the host country’s own reduction targets. Also the rules of the CDM constrain the abatement options that can access this mechanism: only those projects considered “additional” can be registered as CDM projects. If for example currently expensive mitigation options become cheaper, they might no longer fulfil the additionality criterion – if one uses low-hanging

fruit terminology, the fruit starts to “rot”. To date there has not been any comprehensive study assessing what portion of developing countries’ abatement potential is being captured by the CDM.

Furthermore, new emissions abatement options may appear – and become cheaper in time – as technology evolves and as economies grow. The pool of abatement options is thus not a static one, but it may grow in the future, especially in developing countries.

Finally, there is an international market for carbon reduction certificates. Even after one country graduates, there will be other developing countries still under the CDM system, which may continue to deliver cheaper carbon credits (Narain and van’t Veld, 2008). Similarly, as abatement options in some countries become scarce or more expensive, other countries (e.g. Africa, which as present is not playing an important role in the CDM market) will become more mature to enter the CDM market with more force.

#### Modelling the low-hanging fruit issue

So far, only theoretical analyses of the low-hanging fruit problem are available in the literature. Most of these studies focused on answering the question whether developing countries should participate in the CDM or not. Now, most countries have participated in the CDM. The question then turns out to be what the effects of this participation will be for the future climate regime, under the light of the low-hanging fruit hypothesis.

Rose et al. (1999) compared the low-hanging fruit issue with the theory of resource exhaustion: there is a resource stock (carbon emission mitigation options) that is exploited and gradually depleted, which results in rising costs of implementation of emission mitigation projects. The study assumes that both CDM projects and own abatement measures belong to the same pool of mitigation options, which disregards possible differentiation of projects due to the additionality criterion or other entrance barriers for CDM projects. It assumes that the cost of CDM projects is partially or totally compensated by an industrialized country, but that own abatement measures only imply costs for the host country. Technological change is also included in the model. The study finds out that participating in the CDM can impose costs on the future, but these costs can be offset by technological change, market power or compensation. A low-hanging fruit problem exists in the model if the host country is not compensated for this future cost increase.

Rajamani (1999) characterizes unilateral CDM projects as a possible solution to the low-hanging fruit problem. Unilateral projects can be understood in this context as those where the host (developing) country invests in a project, registers it as CDM and then banks, leases or sells the CERs in the international market (see also Michaelowa, 2007 for a more detailed classification and description of unilateral and bilateral CDM projects). While bilateral projects are funded by a buyer in an industrialized country which is mainly interested in acquiring cheap CERs, in unilateral projects it is the seller in the

developing country who bears the project's risks, sets the trading conditions and can push for higher CER prices. As certain project types achieve a CER income much larger than the abatement costs, the gains for the host country from unilateral CDM projects of these types can be considerable. In this case, even if cheap options are used up by the CDM, the profits from the CER sales could compensate for that loss.

Olsen and Painuly (2002) analyze the absolute gains for developing countries from participating or not participating in the CDM by simulating three scenarios for the Kyoto period and a "Kyoto-for-ever" scenario for the post-Kyoto period. They use abatement supply curves from a global general equilibrium model and demand data derived from IEA emissions projections. Assuming that all countries take up emission reduction commitments after Kyoto, they conclude that the CDM is always beneficial for developing countries if their reduction commitments after Kyoto are not linked to their baseline emissions (which are affected by the CDM). Even if their reduction targets are linked to their baseline, they benefit if carbon credit prices are high enough to offset time-discount losses. Market power and technological change can influence the gains.

Akita (2003) develops a simple theoretical model of a developing country with two mitigation options (one low-cost and one high-cost) and two time periods (before and after entering the Kyoto Protocol's Annex B). Several conditions are incorporated in the model, which, according to the author, are necessary for the existence of a low-hanging fruits issue. It assumes developing countries will join the Annex B in the future ("graduation"). After graduation, JI instead of CDM would facilitate technology transfer. The CDM projects would concentrate on the low-hanging fruits. There are cheap abatement options beyond the technological reach of the developing country today and due to technological progress a developing country can undertake an abatement measure tomorrow that it could not undertake today. However, an industrialized country, with more advanced technology, could invest in this project as a CDM today. Such CDM project would induce technological improvements in the developing country. Finally, the model allows that the high-hanging fruits may be harvested before the low-hanging ones. Akita concludes that the low-hanging fruits argument holds, but only for intermediate levels of foreign technology costs and CDM-induced technological development in the country.

Bréchet et al. (2004) consider the possibility that the host country's future emission reduction target may become more stringent if it participates in the CDM, as the post-CDM emissions level may become the baseline to establish the future abatement obligations. This would worsen the low-hanging fruit problem, since not only the cheap options would be taken already, but also the emissions reduction target to be achieved would be more stringent than in a case without CDM. In their model, they also introduce variations in the credit prices, the possibility to bank credits from one period to the other and uncertainty about the future prices of permits. Only unilateral CDM is incorporated in the model. They conclude that developing countries should in general participate in the CDM, unless the credit prices are relatively low during the first period; that banking of credits from one period to the other reduces the low-hanging fruit



problem; and that three effects are likely to limit the extent of CDM participation: endowment effect (the CDM reduces the future allowed emissions quota), irreversibility effect (reduction projects last longer than one commitment period, and thus emissions cannot be larger in the second period than in the first one) and uncertainty effect (of future CER prices).

Narain and van't Veld (2008) sustain that the low-hanging fruits problem does not stem from the fact that the host country will need to use a different, more expensive abatement measure after graduation. They argue that the low-hanging fruit problem originates because the host country gives up the option of delaying the cheap abatement option until graduation and then undertaking it itself. In their paper, they show that the previous characterizations of the low-hanging fruit problem disregard that there is an international carbon credit market. Thus, after graduation, the host country does not necessarily have to invest in more expensive abatement domestically, since it can buy credits from the market. The authors also argue that there is no low-hanging fruit problem under perfect CDM market conditions: with perfect information, the host country can choose whether it approves any specific CDM project or not. However, assuming some form of myopia of the non-Annex B government due to its private interest in the CDM project and/or its impatience (corruption, political instability, lack of human capital or legal infrastructure, lack of knowledge), the low-hanging fruit problem occurs either when the Annex B investors have market power (for example, under a monopsony), or when the credit price is increasing with time and the host country cannot benefit from these rising returns for its CDM project.

Germain et al. (2007) analyze the interaction between the low-hanging fruit issue and the types of CDM project baseline definition: absolute (based on total emissions) or relative (based on the emissions-output ratio) baselines. They assume that CDM projects will be undertaken mostly unilaterally, but also make the analysis for bi- or multilateral projects. They conclude that the low-hanging fruit issue is unfounded for unilateral projects under any type of baseline. It is always optimal for the developing country to implement CDM projects for every strictly positive permits price. Low-cost abatement projects are always implemented first, since the capital-energy ratio is increasing with the permits price. Thus, it is not optimal for the developing country to keep its low-hanging fruit for future use, and it should accept the implementation of all CDM projects up to the optimal capital-energy ratio. Above this threshold, it should receive financial compensation for continuing to implement CDM projects. The endowment effect and increases in the level of uncertainty on future permit prices raise the level of the required compensation. For bilateral or multilateral projects, if the permit price is high at the beginning, the developing country needs to receive a minimal share of the surplus in order to have incentives to accept some CDM projects. Below this minimal share, the country should participate in the CDM only if it is compensated for that.

The results from these theoretical studies imply that the existence of a low-hanging-fruit problem depends on the evolution of carbon credit prices, the way in which future abatement commitments for developing

countries are set, whether CDM projects are developed unilaterally or bilaterally, on the market power of the countries and on the possibility to bank credits from one commitment period to the next.

#### 4. The low-hanging fruit issue in this study

In this paper, we take an approach similar to the one chosen by Rose et al. (1999) for conceptualizing the low-hanging fruit issue: we assume that countries have a stock of emission reduction options, and that part of this stock has been captured by the CDM. By comparing the complete stock to the portion captured by the CDM, we can draw conclusions on whether emission abatement options are being depleted through the CDM, and on which abatement options are being captured: if mostly the cheapest ones are, then the low-hanging fruit argument holds.

This approach is a strong simplification of reality, as it does not take into account the carbon market dynamics that, according to most studies cited above, influences the availability of emission reduction options. Both emissions trading and banking – the possibility to save carbon credits earned today for using (or selling) them in a future period – relax the problem of exhaustion of emission reduction options, as they increase flexibility in achieving emission reduction targets. Economic growth and technological change will make new emission reduction options appear, so that the abatement stock is replenished. Learning effects and technology diffusion will make these new emission reduction options become cheaper in time, so that there will be new low-hanging fruits to pick.

However, in a given moment in time, we can assume that the stock of abatement options available is fixed. As a result, our test of the low-hanging fruit problem relies on two hypotheses:

- Size hypothesis: The larger the portion of the country's mitigation potential (measured in tCO<sub>2</sub>eq) that has been captured by the CDM, the more likely there is a low-hanging fruit problem.
- Cost hypothesis: The larger the portion of the country's *cheap* emission reduction options that has been captured by the CDM (measured in tCO<sub>2</sub>eq), the more likely there is a low-hanging fruit problem.

If under this extreme assumption of no dynamics the CDM is not exhausting the stock of abatement options, we know that the situation must be even better, because the stock will grow in the future. Thus, this assumption leads us to be on the safe side for the analysis.

Our conceptualization of “cheap emission reduction options” relies on the carbon market: we define as cheap all those emission reduction options whose abatement costs are below the average carbon market price for CERs. This is in line with the notion that the market will influence the choice of emission reduction actions: if the market price does not compensate for the cost of mitigation, then it is not financially attractive to engage in this action, and it is preferable to trade carbon credits in the market.

## 5. Data and methods

### CDM cost data

General CDM project information is available from a public database, the CDM pipeline, which is maintained and updated monthly by UNEP Risoe Centre (URC, 2009). More specific information for each project is also publicly available in the project documentation that can be downloaded from the UNFCCC website<sup>4</sup>. This documentation often includes a financial analysis, as this is one possible method for demonstrating that a project complies with the CDM requirement of being additional: if the analysis shows that the project requires the subsidy from the CDM to be financially attractive, then it is deemed additional. The alternative method for demonstrating additionality is a barrier analysis: if the project proponent demonstrates convincingly that there are substantive barriers that prevent the project from taking place without CDM support (for example technological barriers or difficulties in accessing financing), then the project is considered additional.

While this is the only CDM-specific source of financial data that is available, there is a risk of having selection bias because we only get information from those projects choosing to use a financial analysis for additionality demonstration. Indeed, one could think that precisely the projects using the barrier analysis are the low-hanging fruits, and that they do not present their financial data because they are so cheap that they would not pass the additionality test if they did. This suspicion is shared by the CDM regulators, as can be seen in the proposal by the CDM Methodology Panel to enhance the barrier test for projects that are likely to have high revenues (CDM Methodology Panel, 2008) and in the recently adopted “Guidelines for objective demonstration and assessment of barriers” (CDM Executive Board, 2009).

A quick exploration of the data provided by the IGES CDM Project Database (IGES, 2010), which includes information on what type of financial analysis is used in each CDM project, shows that of all CDM projects already registered or seeking registration by the end of 2009, around 35% do not provide any financial data in their public documentation. The factors affecting the decision to include a financial analysis in the CDM project documentation are, as will be discussed in more detail below, not only the technology involved in the project, but also the size of the project, the host country and notably the time passed since the CDM was initiated. This leads us to believe that our data do not suffer from selection bias.

We can assume that the technology involved in the project is the main determinant of the project’s cost. Then, if the cheap technologies never provide financial information, we will have selection bias. In CDM projects, the technology used is roughly given by the “project type”, which is a classification that considers both the economic sector involved (e.g. renewable energy, agriculture, forestry, cement industry) and the

---

<sup>4</sup> Each project has a standardized “Project Design Document” (PDD), which is used throughout the approval process and is publicly available for analysis.

generic technology used to reduce emissions (wind energy, hydro power, reforestation, energy efficiency improvements). In the IGES data, we can see that in terms of project types, only the projects reducing the industrial gas HFC-23 (a very potent greenhouse gas) never perform the financial analysis, which is due to the fact that they do not have any revenues and thus can show their additionality in a simple way. In all other project types (except in those that currently have only one or two projects registered), at least 30% of the projects provide some kind of financial data. Thus, for almost all project types (except HFC-23 and some of those that have only one or two projects registered) we have some cost data available. This minimizes the risk of selection bias.

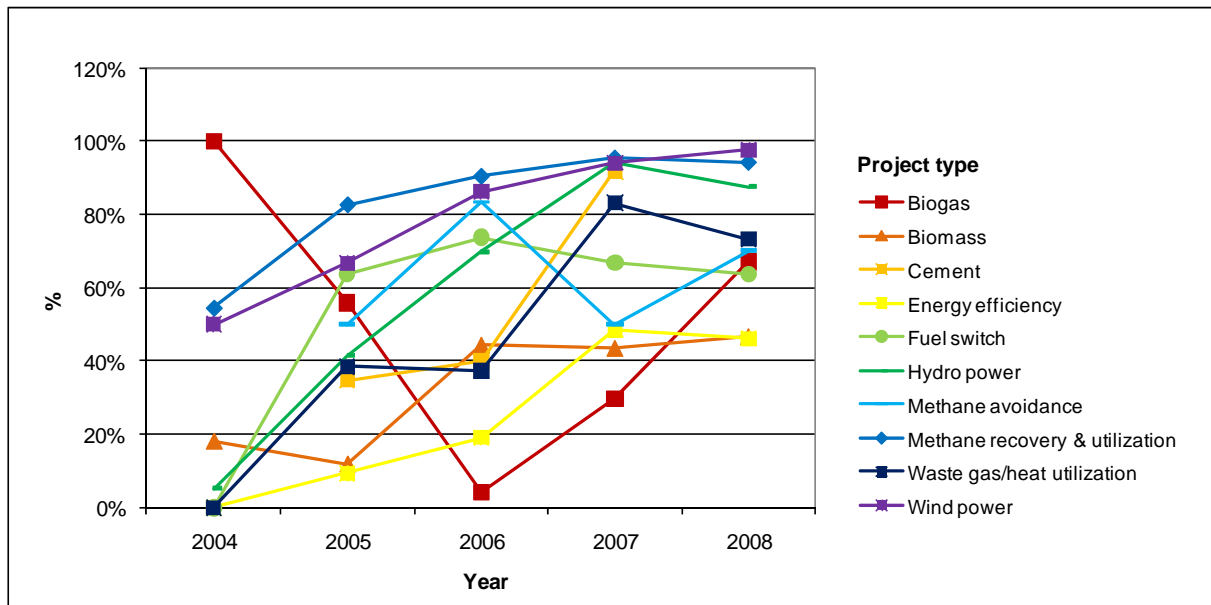
The size<sup>5</sup> of the project is also an important variable affecting the decision to include a financial analysis in the project documentation. Almost 80% of the large CDM projects include a financial analysis, while only 45% of the small ones do. This is related both to the simplified modalities for additionality determination existing for small projects, and to the above-mentioned regulatory mistrust against the barrier test. With respect to the countries, in all main CDM hosts we find both projects performing and not performing a financial analysis, but there are considerable differences: while in China, for example, over 90% of projects include some kind of financial data, in India only 45% do, and in Mexico only 71%. Finally, the time elapsed since the first CDM project was submitted for validation (December 2003) increases the likelihood that a new project includes a financial analysis in its documentation, and this is applicable to most project types, as can be seen in Figure 1. Indeed, as the CDM rules have become clearer and stricter over time, more projects choose to perform an investment analysis to demonstrate additionality.

The financial information is not completely standardized in the PDDs: especially in the early projects, it was sufficient to present some financial indicators of the project (Internal Rate of Return (IRR) or Net Present Value (NPV)) to show whether it is financially attractive or not. This has improved: now large-scale projects opting for a financial analysis must include an excel sheet detailing the project's cash flow. This allows us to verify the assumptions made in the financial analysis and, if needed, standardize them to improve comparability across projects.

---

<sup>5</sup> In the CDM, the size of the project is determined either in terms of its output capacity (for renewable energy projects), the amount of energy consumption reduced (for energy efficiency projects) or the amount of emission reductions achieved (for all other projects) (CDM Rulebook, 2010). Projects considered to be small according to these criteria can use simplified approval methodologies, which include a simplified demonstration of additionality.

**Figure 1: Percentage of registered CDM projects with some kind of financial information in PDDs, according to project type and year of submission for validation**



Source: IGES CDM Project Database, January 4<sup>th</sup>, 2010. Own calculations.

Note: To simplify the graph, HFC, N<sub>2</sub>O, and other project types with very few registered projects are not included. HFC projects never include financial information in their PDDs. N<sub>2</sub>O projects include some kind of financial information in more than 90% of cases. Other renewable energies follow a trend similar to the one for biogas. PFC projects always include financial information. Transportation, material use and leak reduction projects have so far not included any financial information in their PDDs. Data for projects submitted during 2009 is not included, as only very few of these projects have been registered.

#### CDM-specific abatement cost calculation

As shown in Equation 1, we define a project's abatement costs as the net present value of the project costs (investment and operation) minus its revenues (e.g. income from electricity sales), all divided by the amount of GHG emission reductions it expects to achieve (which is indicated by the amount of emission reduction credits the project expects to generate). In fact this is obviously the CDM project abatement cost per tonne of CO<sub>2</sub> equivalents reduced (which is the unit in which greenhouse gas emission reductions are measured). We follow the usual terminology by just speaking about project abatement costs.

$$\text{CDM project abatement cost} = \frac{\text{NPV}(\text{costs}) - \text{NPV}(\text{revenues})}{\text{Amount of GHG emission reductions}} \quad (1)$$

All costs are expressed in US dollars, either using the current interbank exchange rate at the time the project was proposed, or using the exchange rate provided by the project developer in the project documentation.

Time discounting is a critical issue in cost calculations. In capital budgeting, time discounting is used to reflect the interest rates the project is subject to, plus any financial risks applicable to the country where the

investment is taking place, or to the type of investment being made. In the CDM, discount rates are chosen by the project participant, but need to be justified. Still, there is a significant variation in the financial discount rates chosen for projects in different technological categories and in different countries. In order to have comparable information and to avoid the possible effect of financial discount rates being manipulated by project developers to obtain less attractive financial figures<sup>6</sup>, in our calculations the discount rates have been standardized for each country. The discount rate chosen for each country is the median of the discount rates utilized in the CDM projects within our sample taking place in the respective country, which was then rounded to the closest integer. As project developers have to substantiate the parameters they choose for the financial analysis (among them, the choice of the discount rate), we consider the median to be a good indicator of the real discount rate applicable in the country. The median was preferred to the mean because it avoids the influence of outliers. It was preferred to the mode because in several countries no mode was found; nonetheless, in most cases the median and the mode were identical. See Appendix 1 for an overview of host countries and the standardized discount rates applied.

Abatement cost information was extracted from 252 registered<sup>7</sup> CDM projects, covering 29 emission reduction technologies. These projects are mainly located in the eight host countries included in the sample (see below). For technologies where no sufficient financial information was found in these countries, the sample was extended to other countries. For the reason described above, HFC-23 reduction projects, very prominent in advanced developing countries, typically lack financial data in the project documentation and thus abatement cost estimations from secondary sources (Harnisch and Hendricks, 2000; Jimenez, 2005; UNEP TEAP, 2002) have been used.

The abatement cost data were then summarized in terms of the median abatement cost estimated for each technology (or CDM project type) included in the sample.

#### Expected size of CDM emission abatement

As an estimation of the amount of mitigation opportunities the CDM is expected to capture in a country, we aggregate the annual<sup>8</sup> amount of carbon credits that all the CDM projects currently proposed in the country estimate. This information is taken from the CDM pipeline as of end of September 2009 (URC, 2009). This is a very rough estimation, as it does not include new projects that could be proposed in the future, but it includes projects that have been proposed but not yet registered so far. Following current

---

<sup>6</sup> Project developers have an incentive to manipulate their figures and try to show low revenues, so that the project appears financially unattractive, which is a requisite for being considered additional.

<sup>7</sup> A project only gets the CDM status once it has formally been registered by the CDM Executive Board.

<sup>8</sup> CDM projects are entitled to receive CERs only during a specific period of time, the so-called "crediting period". Project developers can choose between a fixed 10-year crediting period or a 7-year crediting period that can be renewed up to two times (thus totalling 21 years). In the discussion about the low-hanging fruit issue, it is generally assumed that the reductions achieved through CDM projects will not be counted towards future emission limitations for their host countries (endowment effect), thus effectively exhausting emission reduction options even after the projects' crediting periods. So, while we measure the emission reductions captured by the CDM annually to ensure comparability, it is to be noted that these emission reductions will be captured over a longer period of time.

project proposal rates (91 projects/month<sup>9</sup>), about 1365 new projects will enter the CDM pipeline until end of 2010. Following current project registration rates (47 projects/month<sup>9</sup>), only about 705 existing projects will be registered. As the CDM pipeline includes 2839 not-yet-registered projects as of end of September 2009, our estimation is likely to be larger than the real size of the CDM by the end of 2010, because many projects in the pipeline will not start generating emission reduction credits yet (unless the registration process accelerates significantly in the following months, which is rather unlikely). Finally, this estimation does not take into account the fact that the emission reductions actually achieved are – for most project types – less than the estimations provided in the project documentation (Castro and Michaelowa, 2008). This all implies that, for our discussion of the low-hanging fruit argument, we are again on the safe side: if a CDM with an overestimated size does not capture a large proportion of the theoretical abatement potential, then the low-hanging fruit issue is not likely to be a real problem.

#### Comparison with theoretical abatement cost studies

From the cost and the size information, marginal abatement cost (MAC) curves for the CDM are built. In order to test the size hypothesis, these curves are compared with MAC curves showing the technical emissions abatement potential in the respective country. These theoretical MAC curves are built by merging the information from several studies that have performed bottom-up assessments of the technologies available for reducing greenhouse gas emissions in individual countries, their costs, and the amount of emission reductions that could potentially be achieved (see the detail of the studies used in Appendix 2). Care was taken to avoid overlaps between the different studies. In order to test the cost hypothesis, a more detailed analysis of the portion of the abatement potential captured by the CDM for different cost categories is made.

#### Case selection

The low-hanging fruit argument is of interest for those developing countries that are under pressure to take more individual action for mitigating climate change. In the climate regime, action towards climate change mitigation is subject to the principle of “common but differentiated responsibilities and respective capabilities” of countries (UNFCCC, 2008: p. 3), which means that countries with more responsibility for causing climate change and with better capabilities to take action should do more. Responsibility can be measured in terms of greenhouse gas emissions levels, in absolute terms or per capita. Capability can be measured in terms of GDP per capita, which is an indication of the economic wealth of the country. Further, the low-hanging fruit problem is potentially relevant only to countries where the CDM has become significant.

Thus, from the countries that are hosting at least 10 registered CDM projects, we selected those that ranked highest in terms of absolute CO<sub>2</sub> emissions, CO<sub>2</sub> emissions per capita and GDP per capita, by building an index that incorporates these three indicators with equal weights. Data was obtained from IEA

---

<sup>9</sup> Average over the last 3 months of 2009.

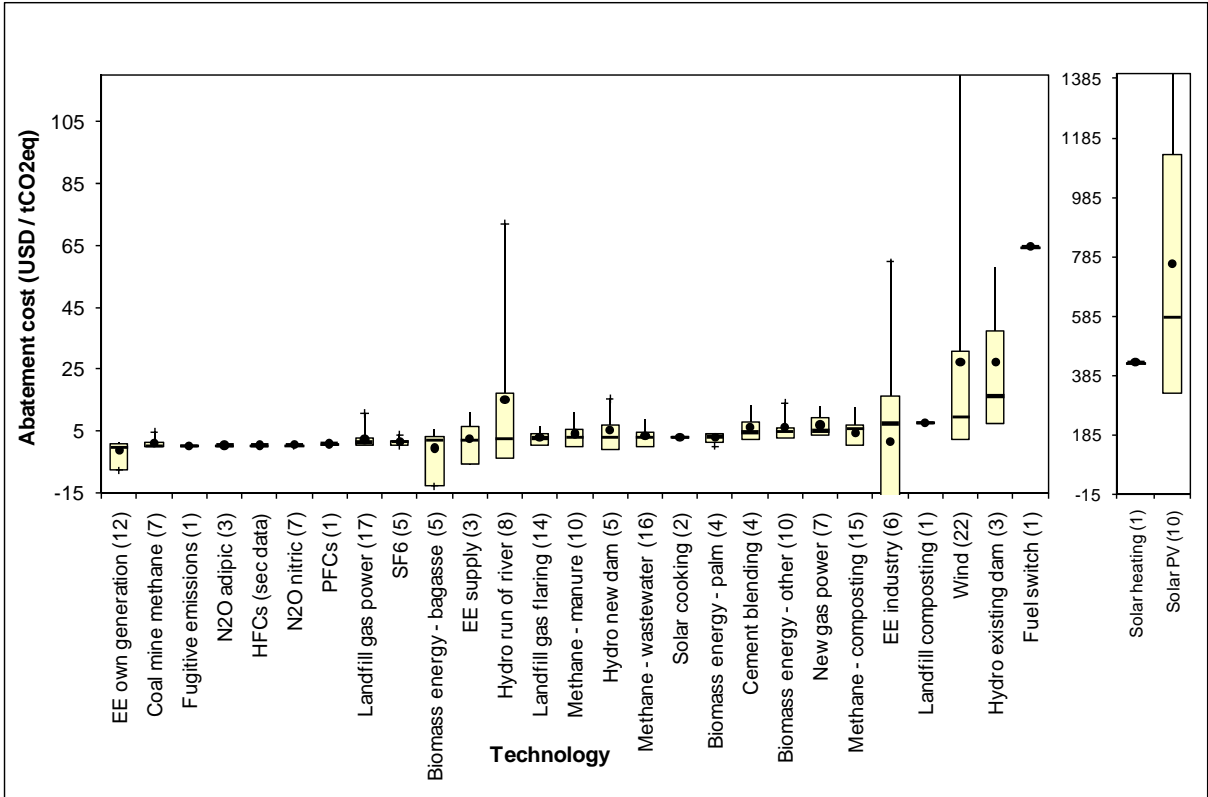
(2007) and IMF (2008). The resulting sample includes China, South Korea, Mexico, South Africa, Thailand, Argentina, Malaysia and Israel. For Malaysia and Israel it was not possible to collect sufficient information for the theoretical abatement cost curves, so that they are discarded from the analysis<sup>10</sup>. However, they have been used for extracting CDM project cost information. Two important CDM host countries (the second and the third with most CDM projects, after China) are India and Brazil. They are, however, not covered in the sample: India has very low levels of emissions per capita and GDP per capita; Brazil has very low emissions per capita and its emissions come mainly from the land use sector, which is currently not covered under the CDM. Finally, Chile had an index value very similar to the one of Argentina. As Argentina has higher absolute emissions, this country was preferred for the analysis.

**6. Results**

CDM abatement costs

Figure 2 shows box plots of the estimated emissions abatement costs of the projects in the sample, after standardizing their financial discount rates.

**Figure 2: Abatement costs of CDM projects (USD/t CO<sub>2</sub> eq), by technology, with standardized discount rates**



Sources: CDM projects' Project Design Documents, own calculations. For HFC projects: Harnisch and Hendricks, 2000; UNEP TEAP, 2002; Jimenez, 2005. The figures in parentheses show the sample size for each technology.

<sup>10</sup> The consultancy Mc Kinsey has prepared a MAC curve for Israel, but the full report is only available in Hebrew, and the executive summary in English does not provide sufficient information for our purposes. Further, it focuses on the year 2030, which is too far away in the future for being comparable with the CDM now.



In these results, it is clear that even after standardizing discount rates, there is still a high variability in cost estimations for some technologies, and that thus these estimations need to be taken with care. However, even with this high variability, our results reproduce very closely the range and ranking of costs reported in abatement cost studies (see e.g. US EPA, 2006; Vattenfall, 2007; Wetzelaer et al., 2007): Methane and industrial gas reduction projects are cheaper than CO<sub>2</sub> reduction projects, basically due to the higher global warming potential of these other gases; renewable energy projects, specifically wind, hydro and solar energy projects are among the costlier ones. All this is consistent with other marginal abatement cost curves and supports our results. The abatement costs of most of these CDM projects are below 20 USD, which is an indication that the emission credit income will make them attractive<sup>11</sup>.

The variability of costs within project subtypes stems from various factors. Above we have already discussed the impact of financial discount rates on the cost estimations. These and other parameters (project lifetimes, inclusion of taxes, inclusion of financing costs) can be manipulated easily to make projects appear non-attractive. However, there are also large differences in the technologies used within project subtypes. For example, methane recovery projects from wastewater can consist of a sophisticated bioreactor, or just of a plastic membrane covering an already existing anaerobic lagoon. Further, biodigesters can be imported or can be manufactured domestically, which will also have an impact on costs. Biomass projects include energy generation from rice husks, bagasse, palm oil residues, forest residues, and a variety of other agricultural or industrial by-products. Energy efficiency projects take place in cement, steel, chemical, petrochemical and other industries and can encompass different efficiency measures. Hydroelectric projects have very different sizes, and smaller ones (among those including a dam) typically imply higher abatement costs. Finally, different countries can have different cost structures, with differing energy prices, taxes or financial incentives for specific technologies that may have an impact on overall abatement costs. Ideally, we should have a different project sample for each host country and estimate country-specific CDM abatement costs, however, due to the fact that most countries still have too few registered CDM projects, this has not been possible.

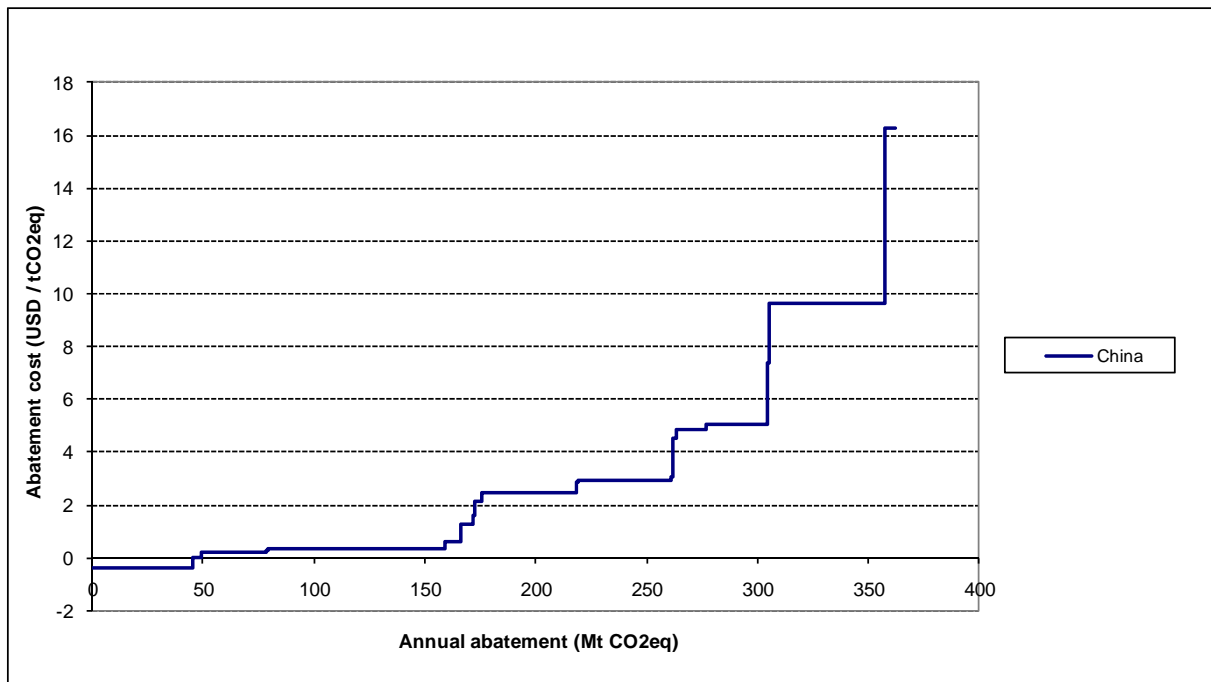
#### CDM abatement cost curves

Figures 3 and 4 show the estimated greenhouse gas abatement cost curves for the Chinese and for the other countries' CDM. As explained above, these curves were built by taking the median abatement cost of each technology (shown in Figure 3) and the amount of emission reductions expected to be achieved annually by all CDM projects in the pipeline as of October 2009 in the respective country, also classified by technologies.

---

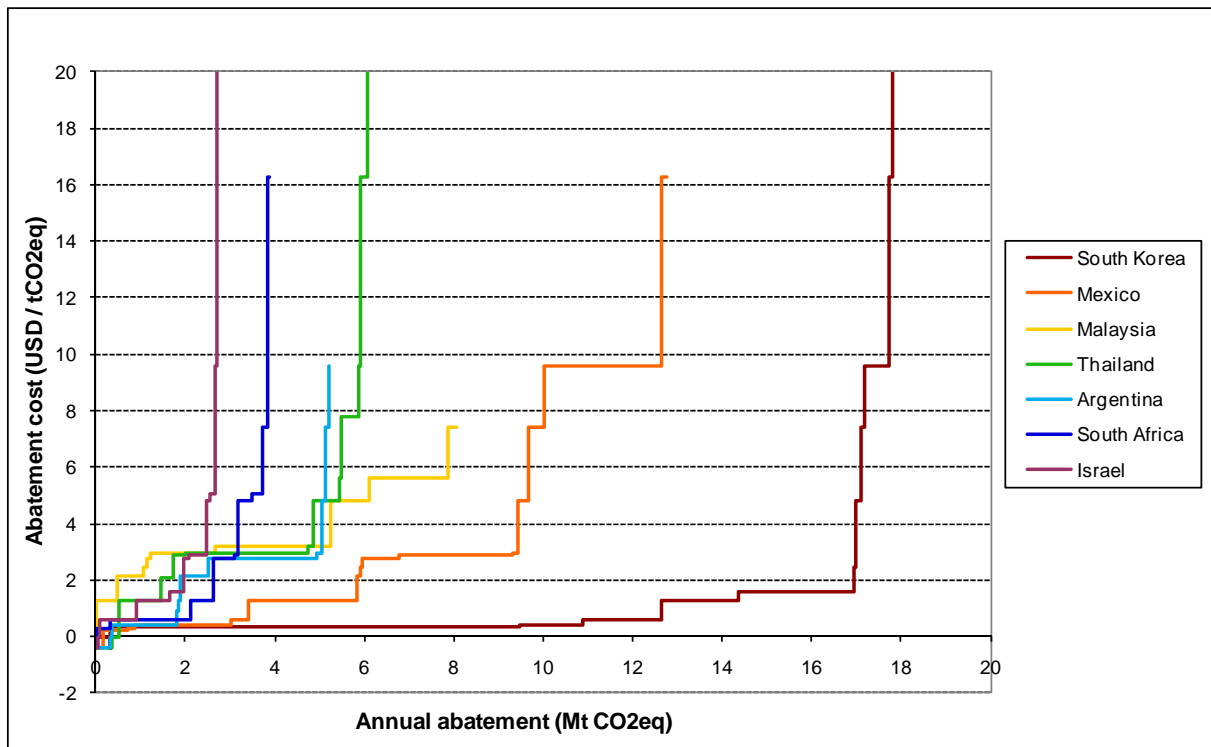
<sup>11</sup> According to the monthly newsletter "CDM Highlights" issued by GTZ, CDM credit prices have fluctuated between USD 12 and USD 33 in the spot market during 2008 and 2009, with an average of USD 20.70.

Figure 3: GHG abatement cost curve for the CDM pipeline: China



Sources: Cost data from PDDs, potentials from URC (2009), own calculations.

Figure 4: GHG abatement cost curve for the CDM pipeline: South Korea, Mexico, Malaysia, Thailand, Argentina, South Africa, Israel



Sources: Cost data from PDDs, potentials from URC (2009), own calculations.

It should be noted that these curves include project types without cost information. These appear at present at the left end of the curves, as having zero abatement costs. The projects without cost information represent 2.3% of the abatement potential in Thailand, 1.8% in South Korea, 1% in China, 0.9% in Argentina, 0.7% in Israel, 0.2% in South Africa, and 0% in Malaysia and Mexico. While this inclusion enlarges the quantity of low-cost (or zero-cost) project options, we opted for not omitting these data from the curves as they allow for a more realistic picture of the overall abatement potential. This enables us again to be on the safe side of the estimations.

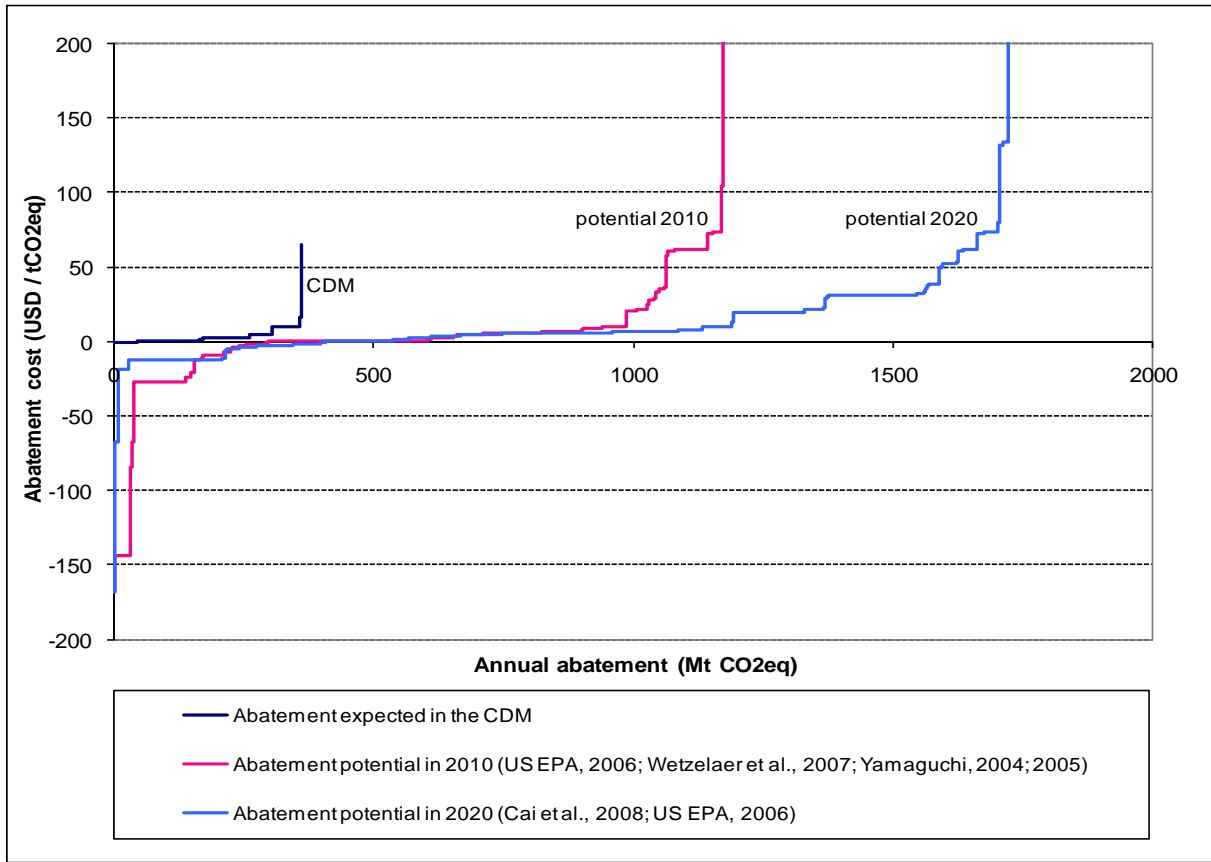
#### Comparison with theoretical abatement curves: size

Based on data reported in 18 climate mitigation studies in the countries included in the sample (see Appendix 2), theoretical greenhouse gas abatement cost curves have been built. Effort has been taken so that as many emission reduction options, from as many sectors (energy, industry, forestry, agriculture) as possible, are included in the curves. Thus, not only CO<sub>2</sub> emissions are considered, but also methane and, when information was available, industrial gas emissions. In all countries, the curves were built to reflect the emissions reduction potential in the year 2010, which should be comparable to the current CDM under the above described (restrictive but safe) assumption of a static stock of mitigation options. In the Chinese case, an abatement curve for the year 2020 has also been included, to provide an idea of how the emissions reduction potential is expected to grow in the future.

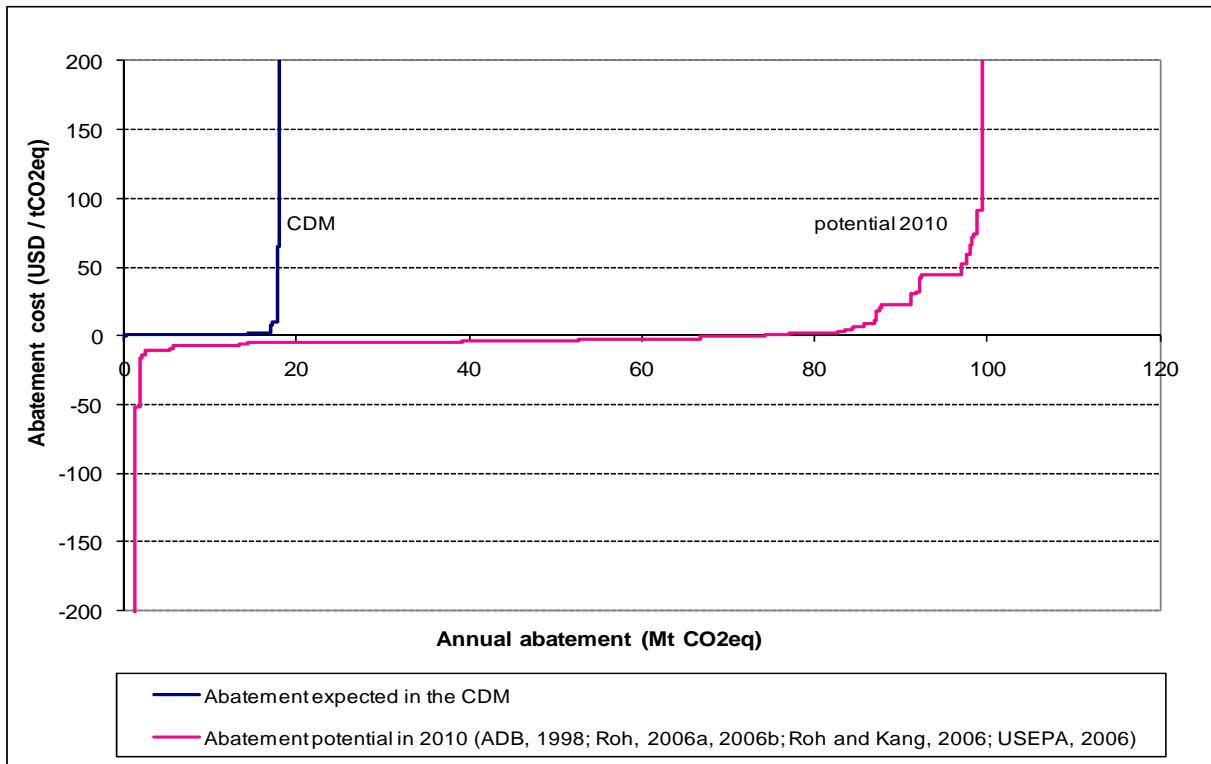
The indicator of the size component of the low-hanging fruit argument is provided by the horizontal difference between the CDM-specific and the theoretical abatement cost curves in each country. This is shown in Figures 5 to 10. Table 1 presents a summary, where we calculate how much of the theoretical abatement potential in each country is being captured by the CDM, by dividing in each case the total abatement expected from the CDM by the total theoretical abatement potential.

Figures 5 to 10 and Table 1 show that, in all cases, the CDM is capturing only a portion of the estimated emissions reduction potential in the respective countries. In China, this portion is around 30%, thus it could be said that there is a risk that the CDM is exhausting the stock of emission reduction possibilities in the country. However, as time passes, new mitigation opportunities arise, so that the current CDM represents only about 20% of the Chinese emission reduction potential in 2020. In South Korea and Argentina, the CDM has captured less than 20% of the potential identified up to 2010, and in Mexico, South Africa and Thailand this portion is below 10%. Thus, we see that in most countries, the risk of a “low-hanging fruit issue” is, at least in terms of the current size of the CDM, weak.

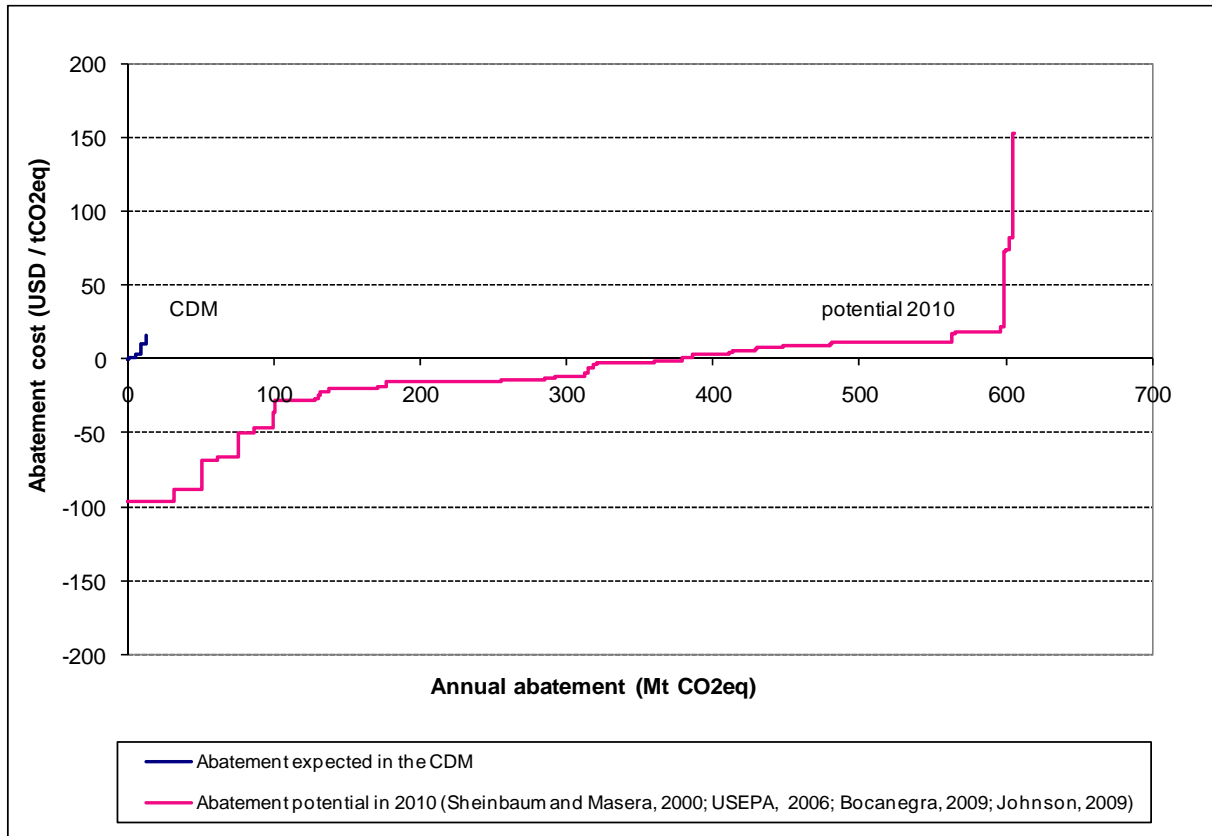
**Figure 5: GHG abatement cost curves in China:**  
**Comparison between expected CDM abatement and potential abatement**



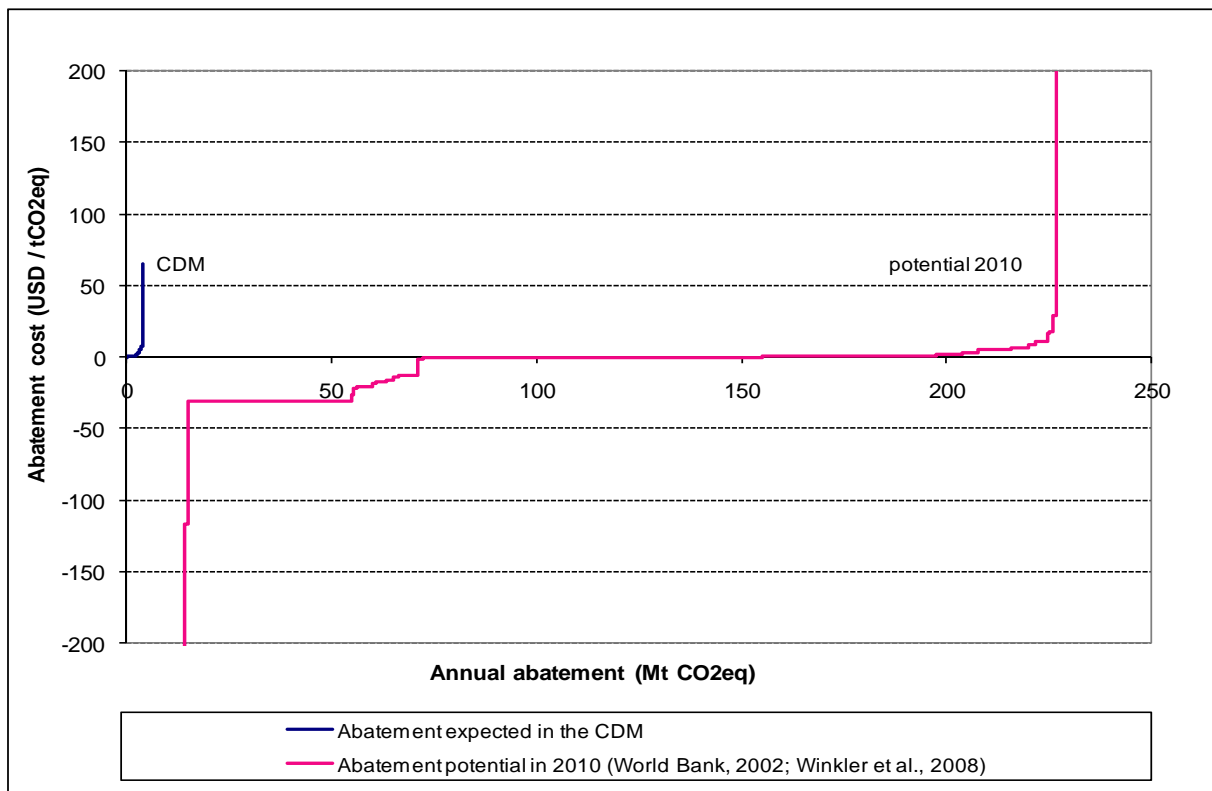
**Figure 6: GHG abatement cost curves in South Korea:**  
**Comparison between expected CDM abatement and potential abatement**



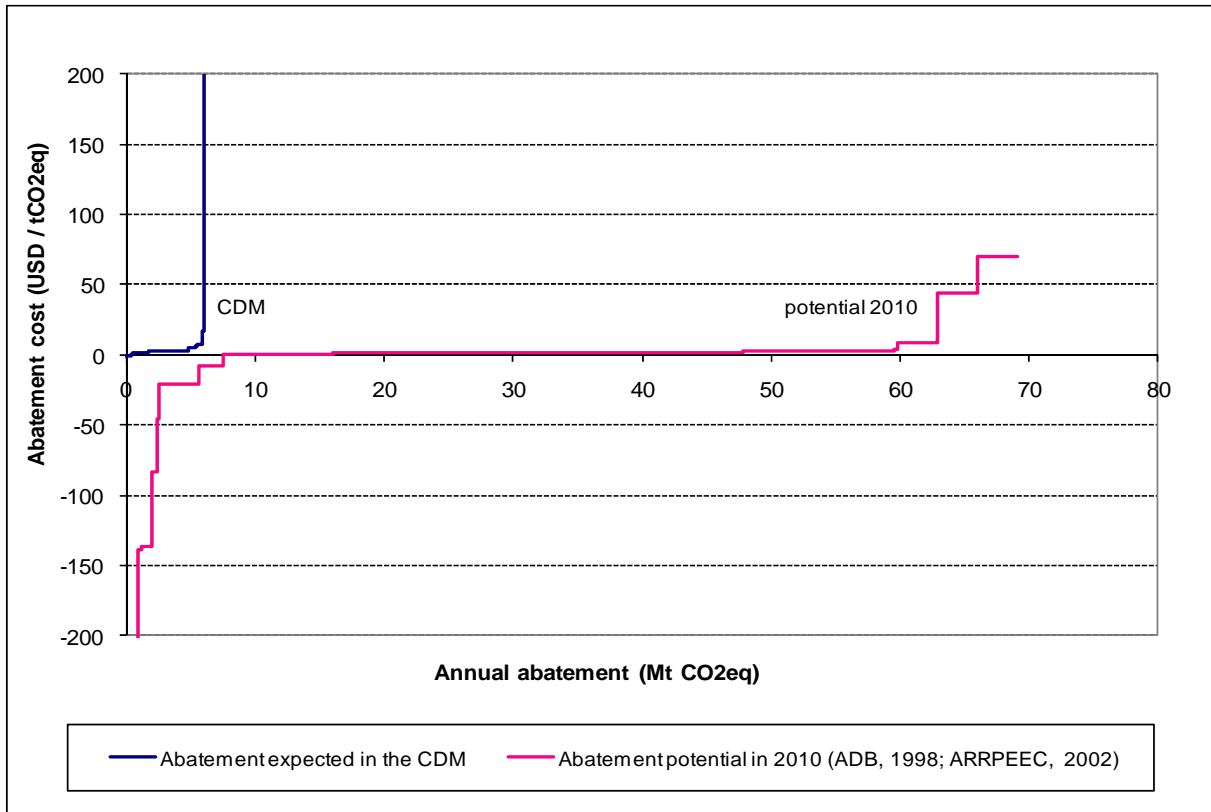
**Figure 7: GHG abatement cost curves in Mexico:**  
**Comparison between expected CDM abatement and potential abatement**



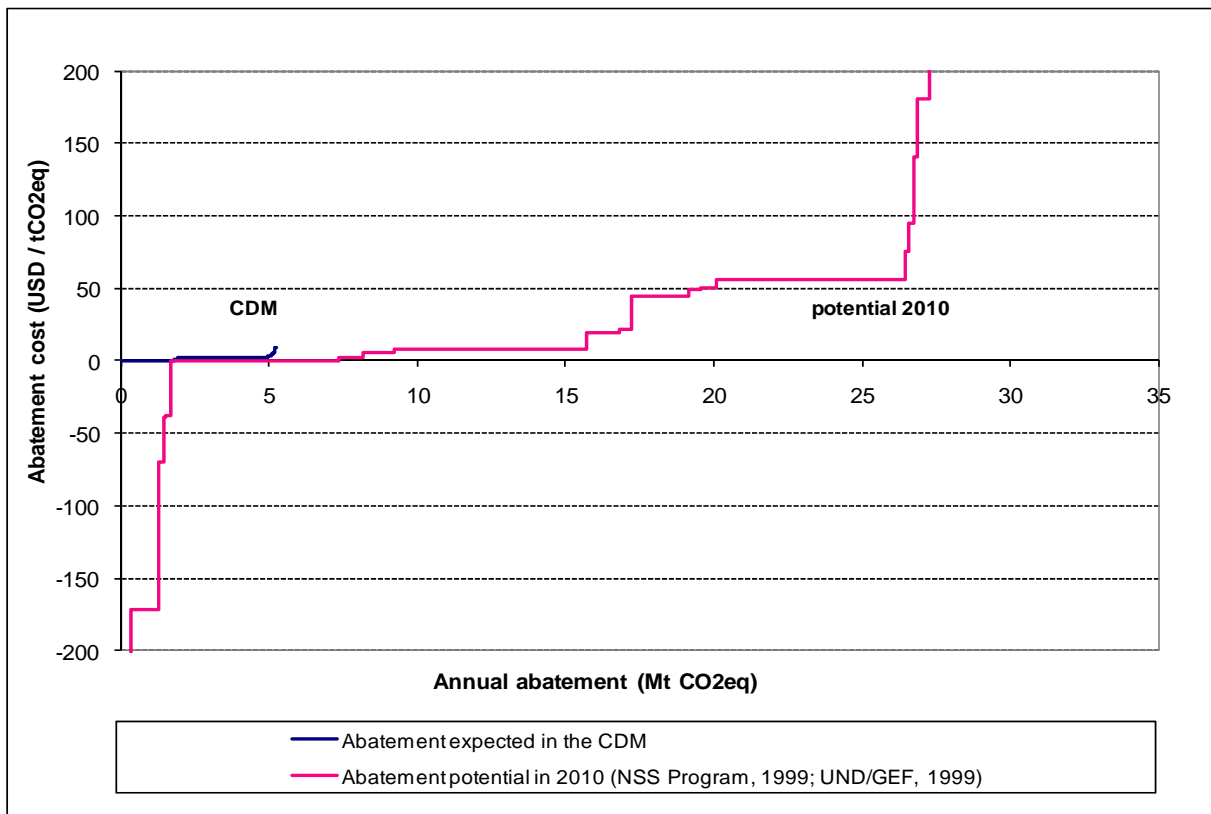
**Figure 8: GHG abatement cost curves in South Africa:**  
**Comparison between expected CDM abatement and potential abatement**



**Figure 9: GHG abatement cost curves in Thailand:**  
**Comparison between expected CDM abatement and potential abatement**



**Figure 10: GHG abatement cost curves in Argentina:**  
**Comparison between expected CDM abatement and potential abatement**



**Table 1: Emissions abatement potential captured by the CDM**

Country	Percentage of abatement potential captured by CDM
China	30.9% of 2010 potential
	21.0% of 2020 potential
South Korea	17.7% of 2010 potential
Mexico	2.1% of 2010 potential
South Africa	1.8% of 2010 potential
Thailand	8.8% of 2010 potential
Argentina	17.6% of 2010 potential

**Table 2: Emissions abatement potential captured by the CDM, by technologies**

Technological category	Percentage of abatement potential captured by CDM					
	China	South Korea	South Africa	Thailand	Mexico	Argentina
Agriculture	0.0%	0.0%	-	-	0.0%	-
Coal mine methane	15.5%	-	0.0%	-	25.7%	-
Energy efficiency in households / commercial buildings	0.0%	0.0%	0.0%	0.0%	0.0%	-
Energy efficiency in industry	0.5%	0.2%	0.3%	0.0%	3.4%	2.2%
Energy efficiency in own generation	19.7%	0.0%	infinite	20.2%	0.4%	75.4%
Thermal power	26.9%	0.0%	2.9%	0.0%	0.1%	-
Forestry	120.0%	0.0%	0.0%	0.0%	0.0%	2.2%
Fugitive emissions	4.4%	0.0%	infinite	-	2.2%	-
Industrial gases	73.1%	209.3%	infinite	infinite	171.9%	infinite
Renewable energy	649.4%	infinite	4.5%	infinite	2.9%	0.7%
Other energy	419.5%	8.2%	0.1%	0.0%	0.0%	35.0%
Waste	7.0%	9.4%	62.3%	infinite	37.1%	48.5%
Transport	Infinite	0.0%	0.0%	0.0%	0.0%	0.0%

Note: “Infinite” denotes a category, for which the theoretical abatement studies did not identify any emission reduction potential, but the CDM did nonetheless. “-“ denotes a category where no emission reduction opportunities were identified, neither in the CDM, nor in the theoretical studies.

Looking in more detail at which technologies have been taken up by the CDM, Table 2 shows what portion of the theoretical potential is being captured by each technological category. The table shows that, in some sectors, such as agriculture and energy efficiency, very little of the identified potential has accessed the CDM. In other sectors, on the contrary, much larger emission reductions are being realized through the CDM than was identified in the theoretical studies, mainly in energy generation from renewable or other sources, or in reduction of industrial gases. On the one hand, it appears that the CDM concentrates in specific technological niches, on the other hand it is clear that the theoretical abatement studies did not uncover all the existing potential. Especially in energy generation, where many countries have experienced an unprecedented growth – for example the explosion of wind power capacity in China since 2006, which

was not foreseen by the analysts –, and where the potential for renewables is difficult to estimate, the projections have been too conservative. Again, because of this, we are on the safe side for drawing conclusions on whether the CDM is exhausting the mitigation potential.

#### Comparison with theoretical abatement curves: costs

In all countries analyzed, the cost range of the CDM projects (vertical axis in the abatement cost curves) covers only a fraction of the theoretical abatement cost range. This can be analyzed in more detail in Table 3. In South Korea and Thailand, we observe that the CDM captures some very costly emission reduction options. These are solar energy projects, which are subsidized in both countries through feed-in tariffs. In China and South Africa, we see that some CDM projects reach abatement costs of nearly 65 USD, which is also above the market price for emission reductions. In Mexico and Argentina, finally, we see that the CDM stays below the 20 USD limit, so that the CER price makes them attractive. From this analysis, we can conclude that in Mexico and Argentina, the CDM seems to be focusing exclusively on the cheaper projects, while in the other countries there is also some exploration of higher cost emission reduction opportunities.

**Table 3: Emissions abatement potential captured by the CDM, by cost categories**

Cost category	Percentage of abatement potential captured by CDM					
	China	South Korea	South Africa	Thailand	Mexico	Argentina
< 0 USD/tCO <sub>2</sub> eq	18.6%	0.1%	0.2%	5.0%	0.0%	18.9%
0 - 10 USD/tCO <sub>2</sub> eq	27.6%	76.1%	2.5%	10.3%	12.4%	34.6%
10 - 20 USD/tCO <sub>2</sub> eq	134.0%	384.2%	0.3%	infinite	0.1%	0.0%
20 - 30 USD/tCO <sub>2</sub> eq	86.5%	0.0%	0.0%	-	0.0%	0.0%
30 - 40 USD/tCO <sub>2</sub> eq	122.5%	2.6%	-	-	-	-
40 - 50 USD/tCO <sub>2</sub> eq	0.0%	0.0%	0.0%	0.0%	-	0.0%
50 - 60 USD/tCO <sub>2</sub> eq	2312.6%	0.0%	-	-	0.0%	0.0%
60 - 70 USD/tCO <sub>2</sub> eq	0.3%	82.2%	infinite	0.0%	-	-
70 - 80 USD/tCO <sub>2</sub> eq	0.2%	0.0%	-	-	0.0%	0.0%
> 80 USD/tCO <sub>2</sub> eq	1.4%	14.0%	0.0%	infinite	0.0%	0.0%

Note: “Infinite” denotes a category, for which the theoretical abatement studies did not identify any emission reduction potential, but the CDM did nonetheless. “-“ denotes a category where no emission reduction opportunities were identified, neither in the CDM, nor in the theoretical studies.

In several theoretical GHG abatement cost studies consulted (Johnson, 2009; Wetzelaer et al., 2007; Enkvist et al., 2007; Bakker et al., 2007; US EPA, 2006; World Bank, 2002; UNDP and GEF, 1999; ADB, 1998), the estimated potential of GHG reduction options with net negative costs is significant. Such “no-regret” reduction options seem to conflict with rational behaviour: if an investment entails negative costs, this means that it is financially profitable, and this business opportunity should have been captured. As reasons for the existence of this negative-cost potential, the literature mentions market imperfections leading to lack of knowledge about the reduction options, misaligned incentives of companies and



consumers, social preferences, lack of priority, lack of investments due to limited financial markets and differing definitions of cost (social versus financial cost). The least-cost abatement measures – especially demand-side energy efficiency measures and modal changes in the transport sector – imply mobilizing millions of diffuse emission sources across many sectors and regions, and thus achieving them may be politically challenging. It is often suggested that in order to remove these market barriers, high transaction costs are incurred that should be added to the technology costs. But these costs are not normally included in abatement cost studies, which mainly rely on merely technical estimations.

The CDM imposes further costs to these abatement options, especially to small-scale ones: monitoring methodologies need to be designed and approved; project design, validation, registration and verification of emission reductions need to be paid for; monitoring plans and equipment need to be put in place. Further, organizing several small emission sources into one project, in order to make it cost-effective, is challenging. It is thus not too surprising that the large reduction potential from energy efficiency and transport, typically with abatement costs below zero, is not being taken up by the CDM.

## **7. Conclusions and limitations of the study**

This paper presents a first attempt to use empirical data for testing the low hanging fruit hypothesis in the CDM – the argument that the CDM is using up the cheaper emission reduction options in its host countries, and leaving them without opportunities for cost-effective emission reductions when they adopt climate change mitigation commitments. By comparing the portion of the emissions reduction potential in six countries captured so far by the CDM with the potential available according to several studies, we conclude that the low-hanging fruit argument is weak.

We find that the CDM is not yet taking up a large portion of the identified theoretical abatement potential in most of the countries assessed, with the exception of China, where it reaches about 30%. In terms of costs, while most of the emissions reduction opportunities grasped by the CDM lie below the 20 USD/tCO<sub>2</sub>eq cost threshold, there is still plenty of low-cost opportunities to be harvested. Finally, while Mexico and Argentina appear to use the CDM exclusively for harvesting the low-hanging fruit, in the other countries analyzed (China, South Korea, Thailand and South Africa), also more expensive projects are accessing the CDM. A more detailed study of the circumstances why these more expensive projects have been captured could shed further light on how to direct the CDM for promoting technologies that are usually difficult to access and for encouraging learning effects, so that new “low-hanging fruits” can be created.

Finally, a note on the limitations of this study. While we have tried to collect data on emission reduction costs and potentials from as many sources as possible, the theoretical potential identified is, as shown above, quite conservative, as witnessed by the many emission reduction options that the CDM captured

without having been identified in the theoretical studies. While this implies that the theoretical MAC curves we have built are to be used with care, it also means that our result – that the CDM is not yet capturing a large portion of this potential – is robust. Further, cost data from CDM projects is likely to be biased downwards for costly technologies and upwards for cheap technologies. The reason for this bias is that CDM projects need to demonstrate that they are financially unattractive without the CDM revenues, but that these revenues make them attractive. The few very expensive projects found in the CDM acknowledged that they were not financially feasible, but that they were intended for demonstration purposes.

## 8. References

ADB (Asian Development Bank) (1998). Asian Least-cost Greenhouse Gas Abatement Strategy (ALGAS) project. Republic of Korea. ADB, GEF, UNDP. Manila, Philippines.

ADB (Asian Development Bank) (1998). Asian Least-cost Greenhouse Gas Abatement Strategy (ALGAS) project. Thailand. ADB, GEF, UNDP. Manila, Philippines.

Akita, J. (2003). A simple model of CDM low-hanging fruit. In: Sawa, T. (editor). International frameworks and technological strategies to prevent climate change. Tokyo: Springer, 66-96.

ARRPEEC (2002). Mitigating environmental emissions from the power sector: analysis of technical and policy options in selected Asian countries. Asian Regional Research Programme in Energy, Environment and Climate. Presentation at COP 8 (1st November 2002). New Delhi.

Bakker, S.J.A.; Arvanitakis, A.G.; Bole, T.; van de Brugg, E.; Doets, C.E.M.; Gilbert, A. (2007). Carbon credit supply potential beyond 2012 – A bottom-up assessment of mitigation options. ECN, PointCarbon, ECOFYS.

Bang G.; Heggelund, G.; Vevatne, J. (2005). Shifting strategies in the global climate negotiations. Oslo: Center for International Climate and Environmental Research, and Lysaker: The Fridtjof Nansen Institute.

Barker, T.; Bashmakov, I.; Alharthi, A.; Amann, M.; Cifuentes, L.; Drexhage, J.; Duan, M.; Edenhofer, O.; Flannery, B.; Grubb, M.; Hoogwijk, M.; Ibitoye, F.I.; Jepma, C.J.; Pizer, W.A.; Yamaji, K. (2007). Mitigation from a cross-sectoral perspective. In: Metz, B.; Davidson, O.R.; Bosch, P.R.; Dave, R.; Meyer, L.A. (eds). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge (UK) and New York (USA): Cambridge University Press.

Baumert, K.A.; Kete, N. (2002). Will the Kyoto Protocol drive industry to developing countries? Earth Trends Featured Topic. Washington, D.C.: World Resources Institute.

Bocanegra, J. (2009). PEMEX methane emissions inventory and marginal abatement cost analysis. PEMEX, USEPA, Methane to Markets.

Bréchet, T.; Germain, M.; van Steenberghe, V. (2004). The clean development mechanism under the Kyoto Protocol and the 'low-hanging fruits' issue. CORE Discussion Paper, 2004/81. CORE, Université Catholique de Louvain.

Cai, W.; Wang, C.; Chen, J.; Wang, K.; Zhang, Y.; Lu, X. (2008). Comparison of CO<sub>2</sub> emission scenarios and mitigation opportunities in China's five sectors in 2020. *Energy Policy* 36: 1181-1194.

Castro, P.; Michaelowa, A. (2008). Empirical analysis of performance of CDM projects. Climate Strategies Report. Cambridge, UK: Climate Strategies.

CDM Executive Board (2009). Guidelines for objective demonstration and assessment of barriers (version 01). Annex 13 to the Executive Board Meeting 50, October 16, 2009.

CDM Methodology Panel (2008). Proposal for an enhanced barrier test for project activities that have a potentially high profitability without CER revenues. Annex 11 to the Methodology Panel Meeting 33, June 23-27, 2008.

CDM Rulebook (2010). Small-Scale > Eligible projects > What are small-scale projects? URL: <http://cdmrulebook.org/152> (accessed 29.01.2010).

Cosbey, A. (2005). Climate change and competitiveness. A survey of the issues. Background paper for workshop on Climate Change, Trade and Competitiveness at Chatham House, London. Winnipeg: International Institute for Sustainable Development.

Criqui, P.; Mima, S.; Viguier, L. (1999). Marginal abatement costs of CO<sub>2</sub> emission reductions, geographical flexibility and concrete ceilings: an assessment using the POLES model. *Energy Policy*, 27: 585-601.

Ellerman, A.D.; Decaux, A. (1998). Analysis of Post-Kyoto CO<sub>2</sub> emissions trading using marginal abatement curves. Report 40, MIT, Joint Program on the Science and Policy of Global Change.

Enkvist, P.-A.; Naucler, T.; Rosander, J. (2007). A cost curve for greenhouse gas reduction. *The McKinsey Quarterly* 1: 34-45.

European Commission. (2008). Competitiveness aspects of sustainable development: climate change. URL: [http://ec.europa.eu/enterprise/environment/index\\_home/climate\\_change/climate\\_change.htm](http://ec.europa.eu/enterprise/environment/index_home/climate_change/climate_change.htm) (accessed 12.08.2008).

Germain, M.; Magnus, A.; van Steenberghe, V. (2007). How to design and use the clean development mechanism under the Kyoto Protocol? A developing country perspective. *Environmental and Resource Economics*, 38: 13-30.

Green, G.A. (2008). A quantitative analysis of the cost-effectiveness of project types in the CDM pipeline. Master's thesis at Institute of Food and Resource Economics, University of Copenhagen. CD4CDM Working Paper No. 4. Roskilde: UNEP Risoe Centre.

Gupta, S.; Tirpak, D.A.; Burger, N.; Gupta, J.; Höhne, N.; Boncheva, A.I.; Kanoan, G.M.; Kolstad, C.; Kruger, J.A.; Michaelowa, A.; Murase, S.; Pershing, J.; Saijo, T.; Sari, A. (2007). Policies, Instruments and Co-operative Arrangements. In: Metz, B.; Davidson, O.R.; Bosch, P.R.; Dave, R.; Meyer, L.A. (eds). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge (UK) and New York (USA): Cambridge University Press.

Harnisch, J.; Hendricks, C. (2000). Economic Evaluation of Emission Reductions of HFCs, PFCs and SF6 in Europe. Brussels.

Höhne, N.; Filho, G.M.; Marcovitch, J.; Yamin, F.; Moltmann, S. (2007). History and status of the international climate negotiations on a future climate agreement. BASIC Paper 15.

Hourcade, J.C.; Shukla, P.; Cifuentes, L.; Davis, D.; Emonds, J.; Fisher, B.; Fortin, E.; Golub, A.; Hohmeyer, O.; Krupnick, A.; Kverndokk, S.; Loulou, R.; Richerls, R.; Segenovic, H.; Yamaji, K. (2001). Global, regional, and national costs and ancillary benefits of mitigation. In: Metz, B.; Davidson, O.; Swart, R.; Pan, J. (eds). *Climate Change 2001—Mitigation. Report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 499-559.

IEA (International Energy Agency) (2007). *Key World Energy Statistics*. Paris: OECD/IEA.

IGES (Institute for Global Environmental Strategies) (2010). IGES CDM Project Database, January 4<sup>th</sup>, 2010.

IMF (International Monetary Fund) (2008). *World Economic Outlook Database April 2008*. Available at: <https://www.imf.org/external/pubs/ft/weo/2008/01/weodata/index.aspx> (accessed 10/09/2008).

Jimenez, G. (2005). Policy alternatives for abatement of HFC-23 emissions in China. Presentation at Sino Italian workshop on HFC 23 CDM Projects in China, Beijing, 24 January 2005.

Johnson, T.M. (2009). Low carbon development for Mexico (MEDEC). World Bank, LCR Sustainable Development Department, September 10, 2009.

McKittrick, R. (1999). A derivation of the Marginal Abatement Cost Curve. *Journal of Environmental Economics and Management*, 37: 306-314.

Michaelowa, A. (2007). Unilateral CDM – can developing countries finance generation of greenhouse gas emission credits on their own? *International Environmental Agreements*, 7: 17-34.

MNP (Netherlands Environmental Agency) (2008). Global CO<sub>2</sub> emissions: increase continued in 2007. Available at: <http://www.mnp.nl/en/publications/2008/GlobalCO2emissionsthrough2007.html> (accessed 03/09/2008).

Narain, U.; van't Veld K. (2008). The Clean Development Mechanism's low-hanging fruit problem: when might it arise, and how might it be solved? *Environmental and Resource Economics*, 40(3): 445-465.

NSS Program (1999). Study on flexibility mechanisms within the context of the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Buenos Aires, June 1999.

Olsen, K.H. (2007). The clean development mechanism's contribution to sustainable development: a review of the literature. *Climatic Change*, 84: 59-73.

Olsen, K.R.; Painuly, J.P. (2002). The Clean Development Mechanism: a bane or a boon for developing countries? *International Environmental Agreements: Politics, law and economics*, 2: 237-260.

Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; and co-authors. (2007). Technical Summary. In: Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; van der Linden, P.J.; Hanson, C.E. (Eds.). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge (UK): Cambridge University Press, 23-78.

Rajamani, L. (1999). Kyoto to Buenos Aires, Bonn and beyond. In: *Tiempo Climate Cyberlibrary*, 33. URL: <http://www.cru.uea.ac.uk/tiempo/portal/archive/issue33/t33a5.htm> (accessed 07/04/2008).

Roh, D.W. (2006a). Potential estimation for GHG emissions reduction and energy efficiency in manufacturing industry II (oil refining industry) - Using bottom-up optimization model (MARKAL). Summary available at: [http://www.keei.re.kr/main.nsf/index\\_en.html](http://www.keei.re.kr/main.nsf/index_en.html) (Korea Energy Economics Institute).

Roh, D.W. (2006b). Estimation of Potential for Emissions Reductions and Energy Savings in Manufacturing Industry I (Cement industry). Summary available at: [http://www.keei.re.kr/main.nsf/index\\_en.html](http://www.keei.re.kr/main.nsf/index_en.html) (Korea Energy Economics Institute).

Roh, D.W., Kang, Y.Y. (2006). Study of the effects of policies on greenhouse gas emission reduction on the productivity of the manufacturing industry. Summary available at: [http://www.keei.re.kr/main.nsf/index\\_en.html](http://www.keei.re.kr/main.nsf/index_en.html) (Korea Energy Economics Institute).

Rose, A.; Bulte, E.; Folmer, H. (1999). Long-run implications for developing countries of joint implementation of greenhouse gas mitigation. *Environmental and Resource Economics*, 14: 19-31.

Sheinbaum and Masera (2000). Mitigating carbon emissions while advancing national development priorities: the case of Mexico. *Climate Change* 47: 259-282.

Tangen, K.; Heggelund, G. (2003). Will the Clean Development Mechanism be effectively implemented in China? FNI Report 8/2003. Lysaker, Norway: The Fridtjof Nansen Institute.

UNDP and GEF (1999). Economics of greenhouse gas limitations. Country study series. Published by the UNEP Collaborating Centre on Energy and Environment, Risoe National Laboratory.

UNEP Technology and Economic Assessment Panel. (2002). Report of the TEAP Report of the Task Force on Destruction Technologies. Nairobi.

UNFCCC (2008). Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007 – Addendum. Part two: Action taken by the Conference of the Parties at its thirteenth session. Decision 1/CP.13 – Bali Action Plan. FCCC/CP/2007/6/Add.1.

URC (UNEP Risoe Center) (2009). CDM/JI Pipeline Analysis and Database, October 1<sup>st</sup>, 2009.

US EPA (2006). Global mitigation of non-CO<sub>2</sub> greenhouse gases - technical annex.

Vattenfall (2007). Global mapping of greenhouse gas abatement opportunities. Power point presentation, January 2007.

Wara, M. (2006). Measuring the Clean Development Mechanism's performance and potential. PESD Working Paper 56. Stanford: University of Stanford, Program on Energy and Sustainable Development.

Wetzelaer, B.J.H.W.; van der Linden, N.H.; Groenenberg, H.; de Coninck, H.C. (2007). GHG Marginal Abatement Cost curves for the Non-Annex I region. Petten: ECN – Energy Research Centre of the Netherlands.

Winkler, H., Marquard, A., Manley, J., Davis, S., Trikam, A., Den Elzen, M., Höhne, N., Witi, J. (2008). Quantifying SD-PAMs: National energy models and international allocation models for climate change mitigation. South African case study. Energy research Centre, University of Cape Town, South Africa.

World Bank (2002). South African National Strategy Study on the Clean Development Mechanism.

WRI (World Resources Institute). (2008). CAIT: Climate Analysis Indicators Tool, Version 5.0. (2008). Washington, D.C.: World Resources Institute. URL: <http://cait.wri.org/> (accessed 12.08.2008).

WRI (2009). Summary of UNFCCC submissions. August 2008 – October 2009, 2009. Working paper. Washington, D.C.: World Resources Institute.

Yamaguchi, M. (2004). CDM potential of electric power sector and energy-intensive industries in China. Outcome of 5-year joint study of Keio University / Tsinghua University.

Yamaguchi, M. (2005). CDM potential in the power-generation and energy-intensive industries of China. *Climate Policy* 5: 167-184.



### Appendix 1: Standardization of discount rates

Country	Standardized discount rate
Argentina	10%
Brazil	15%
China	8%
India	12%
Indonesia	12%
Israel	10%
Kenya	15%
Malaysia	10%
Mexico	12%
Morocco	15%
Qatar	10%
South Africa	12%
South Korea	7%
Thailand	10%
United Arab Emirates	8%

## Appendix 2: Sources of data for theoretical MAC curves

Country	Data sources
Argentina	National CDM/JI Strategy Studies (NSS) Program, 1999; UNDP/GEF, 1999
China	Yamaguchi, 2004; Yamaguchi, 2005; US EPA, 2006; Wetzelaer et al., 2007; Cai et al., 2008
Mexico	Sheinbaum and Masera, 2000; US EPA, 2006; Bocanegra, 2009; Johnson, 2009
South Africa	World Bank, 2002; Winkler et al., 2008
South Korea	Asian Development Bank, 1998; Roh, 2006a; Roh, 2006b; Roh and Kang, 2006; US EPA, 2006
Thailand	Asian Development Bank, 1998; Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC), 2002