# BENEFITS OF THE CLEAN DEVELOPMENT MECHANISM 2012

**United Nations**
Framework Convention on
Climate Change

CLEAN DEVELOPMENT MECHANISM

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# EXECUTIVE SUMMARY

The end of the first commitment period of the Kyoto Protocol (2008–2012) marks a turning point in the history of the clean development mechanism (CDM). This junction warrants posing the question: Did the CDM fulfil its initial design objectives and were there any other benefits?

The CDM was designed to meet two objectives, namely to help Annex I Parties to cost-effectively meet part of their emission reduction targets under the Kyoto Protocol and to assist non-Annex I Parties in achieving sustainable development. While CDM projects create certified emission reductions (CERs) that project participants can sell to Annex I Parties to help them meet their Kyoto Protocol targets, they can also provide complementary benefits to non-Annex I Parties such as new investment, the transfer of climate-friendly technologies and knowledge, the improvement of livelihoods and skills, job creation and increased economic activity.

United Nations Climate Change Secretariat has analysed aspects of CDM project activities and reported on the levels and types of benefits the CDM has provided. Expanding on the study in 2011, this report analyses approximately 4,000 registered CDM projects (excluding programmes of activities) according to four topics: sustainable development, technology transfer, finance and regional distribution.

## SUSTAINABLE DEVELOPMENT

Since the registration of the first CDM project in 2004, scholars and policymakers alike have attempted to understand how the CDM contributes to sustainable development. All of the studies rely mainly on information provided in project design documents and they use different indicators of sustainable development. Various positive impacts with benefits distributed across economic, environmental, and social areas is claimed for all project types. Some studies claim that hydrofluorocarbon (HFC) and nitrous oxide ($N_2O$) projects yield the fewest sustainable development benefits. Other studies suggest a trade-off in favour of producing low-cost emission reductions at the expense of achieving sustainable development.

This study assesses the claims made by project participants in the project design documents submitted for registration. The relative reliability of these claims, as verified by a follow-up survey, suggests that the CDM is making a contribution to sustainable development in host countries in addition to the mitigation of greenhouse gas (GHG) emissions. Almost all CDM projects claim multiple sustainable development benefits, but the mix of benefits claimed varies considerably by project type.

The most prominent benefit claimed is stimulation of the local economy through employment creation and poverty alleviation, followed by reduction of pollution and promotion of renewable energy and energy access. The mix of benefits claimed has not changed significantly since the first CDM project was registered, except that claims of environmental and noise pollution reduction have become more common.

Under the CDM modalities and procedures, each non-Annex I Party (host country) has the authority to assess whether a CDM project contributes to sustainable development according to national development priorities. A comparison of projects across different countries shows that the host country has an effect on the mix of benefits claimed by a project. However, social benefits tend to be cited (or possibly required of projects) less often than economic and environmental benefits in all countries.

There is room for improvement in both the standards and approaches used for the declaration of sustainable development of CDM projects, as confirmed by many other studies.

## TECHNOLOGY TRANSFER

There is no doubt that the CDM facilitates technology transfer to host countries. Approximately a third of all projects claim to import equipment and/or knowledge. This understates the extent of technology transfer because it is now known that more than half of the projects that do not claim technology transfer use technologies from other CDM projects or imported knowledge and/or equipment.

This study, and others, show that the frequency of technology transfer declines over time as local expertise related to the relevant technologies grows. CDM project activities help develop this expertise; the frequency of technology transfer declines as the number of projects of a given type in a host country increases. The frequency of technology transfer via CDM projects has declined over time in China, India and Brazil – the countries that host the largest numbers of projects – but remains high in almost all other host countries.

The frequency of technology transfer differs significantly by project type and by host country. Not surprisingly, the rate of technology transfer is lowest for hydro and cement projects, which use mature technologies already widely available in developing countries. Many countries have requirements related to the technology used by CDM projects, separately or as part of their sustainable development criteria, which explains why the host country has an impact on the frequency of technology transfer.

A comparison of technology transfer in projects across different countries shows that CDM host country characteristics, such as population, GDP per capita, foreign direct investment, renewable share of electricity generation and knowledge stock significantly impact the rate of technology transfer via the CDM. Furthermore, a change to these host country characteristics has an almost immediate effect (after just one to two years) on the rate of technology transfer. Efforts to identify the specific characteristics that influence the rate of technology transfer have made some progress, but further research is needed.

Innovation on climate mitigation technologies occurs primarily in developed countries with the top five technology suppliers for CDM projects being Germany, the USA, Denmark, Japan and China. Within these countries there tend to be many technology suppliers indicating that project developers have a choice among a number of domestic and/or foreign suppliers with no dominant supplier able to restrict the distribution of the technology and/or keep the price high.

## FINANCE

The total investment in registered or soon-to-be-registered CDM projects as of June 2012 is estimated at USD 215.4 billion. The investment in projects that are known to be operating is USD 92.2 billion. The annual investment peaked in 2008 at USD 13.9 billion (operating projects) and USD 40.4 billion (all projects), but the large number of projects undergoing validation could lead to a new, much higher, peak in 2012 or thereafter.

The average investment per project is approximately USD 45 million. China and India which make up the bulk of projects in Eastern Asia and Southern Asia respectively account for 65 per cent of the total investment with 45 per cent of the projects. Projects in Eastern Asia have relatively large capital investment due to the capital-intensive nature of the projects undertaken (renewables) and their large average size. In contrast, the capital investment per project of almost every other region is equal to or below the overall average. A comparison of renewable energy CDM projects with similar projects in Annex I countries shows that CDM projects are often much larger and less capital-intensive (lower cost per MWe of capacity) than corresponding projects in Annex I countries.

Approximately 90 per cent of CDM projects and 65 per cent of similar renewable energy projects in Annex I countries are solely domestically financed. However, there is a strong indication that the share of foreign investment is increasing in both CDM and Annex I country projects. The pattern of foreign investment in CDM projects is complex, with funds coming from both developed and developing countries and often from multiple countries for a single project.

Most CDM project types have an average estimated mitigation cost below 10 USD per tonne of carbon dioxide equivalent (t $CO_2$ e). These costs vary significantly by project type, with solar being the most expensive technology deployed in the CDM (>300 USD/t $CO_2$ e). The average mitigation cost has increased over time, which reflects the change in the mix of project types with fewer low-cost industrial gas projects in recent years. However, it may also reflect a more stringent assessment of additionality over time leading to fewer project activities that are economically viable without the revenue from the sale of CERs.

There is evidence of economies of scale – lower mitigation cost per tonne of $CO_2$ e for larger projects – for some types such as renewable, forestry and transport projects, and diseconomies of scale – higher mitigation cost per tonne of $CO_2$ e for larger projects – for others such as demand-side energy efficiency, supply-side energy efficiency, and methane avoidance project activities.

Over 750 million CERs had been transferred from the CDM registry by the end of 2011. The revenue generated by the sale of these CERs is estimated to be at least USD 9.5 billion and possibly as much as USD 13.5 billion.

Savings for Annex I countries through the use of CERs are estimated to be at least USD 3.6 billion for 2008 to 2012. The CDM is projected to reduce compliance costs for firms in the European Union Emissions Trading System and in Japan by at least USD 2.3 billion for the period 2008 through 2012. The estimate is based on the difference between CER prices and European Union Allowance (EUA) prices. Since CERs also had the effect of lowering the price of EUAs, the estimate understates the savings. The use of CERs by Annex I Party governments to meet their 2008 to 2012 national emission limitation commitments is expected to yield an additional USD 1.3 billion in savings.

Furthermore, other studies suggest that investors focus on projects with low abatement cost so the CDM market is working relatively efficiently. They also suggest, however, that there is still significant untapped potential for CDM projects even in countries with many CDM project activities.

## REGIONAL DISTRIBUTION

Although the text of the Kyoto Protocol does not refer to the regional distribution of CDM project activities, it has long been a concern of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP). The CMP has never defined “equitable regional distribution”, so there is no benchmark against which to compare the evolving distribution of project activities.

As a market mechanism, the distribution of CDM project activities and CERs has generally matched the distribution of mitigation potential across countries as represented by national emissions and economic development. Although the number of host countries continues to grow, many countries with small economies and low GHG emissions have few, if any, CDM projects. These include many countries in Africa and the least developed countries (LDC) group, as well as some in Asia. Various initiatives, both under and outside the Kyoto Protocol, have been implemented with the aim of increasing the number of CDM projects in such countries. It is too early to assess whether they have been successful. Having a strong institutional capacity for the CDM is necessary but not sufficient to attract projects. As many CDM project activities are domestically financed, a lack of access to early stage seed funding for CDM costs and high unit transaction costs are significant barriers in many poorer countries. The lack of underlying project finance prevents CDM projects from moving ahead in under-represented countries.

The CDM appears to have fulfilled large parts of its initial design objective. It has created value and resulted in complementary benefits that were not conceived at the design stage. Some of these include cost-effective mitigation and resultant savings for Annex I country participants and governments, new and possibly additional investment, transfer of and knowledge in climate-friendly technologies, and job creation and increased economic activity for non-Annex I Parties. There is also evidence indicating what measures could be undertaken so that these benefits could be realized in countries with little or no exposure to the CDM.

# I. INTRODUCTION

The end of the first commitment period of the Kyoto Protocol (2008–2012) marks a turning point in the history of the clean development mechanism (CDM). This junction warrants posing the question: Did the CDM fulfil its initial design objectives and were there any other benefits?

The CDM was designed to meet two objectives, to assist Annex I Parties in complying with their emission limitation and reduction commitments and to assist non-Annex I Parties in achieving sustainable development and in contributing to the ultimate objective of the United Nations Convention on Climate Change (i.e. to achieve a stabilization of atmospheric GHG concentrations at a level that will prevent dangerous human induced interference with the climate system). Although CDM projects create certified emission reductions (CERs) that project participants can sell to Annex I Parties to help them meet their Kyoto Protocol targets, they can also provide complementary benefits, such as the transfer of technology, rural energy provision, reduction of pollutants, contributions to livelihood improvement, employment creation and increased economic activity.

In the same vein as the 2011 study (UNFCCC, 2011), this report presents further evidence relating to the benefits and impacts of the CDM in time for the end of the first commitment period of the Kyoto Protocol. Specifically the CDM's contributions to sustainable development and to technology transfer are examined as well as emerging patterns in CDM capital investment, costs, savings and revenue and the geographic distribution of projects. Throughout this study it is assumed that co-benefits associated with CDM projects are solely due to the influence of the CDM, although there may be benefits which could be derived from other project baseline scenarios.

The evidence comes from six sources of information:

- UNFCCC (CDM) Analytical Database as of June 2012 – a database maintained by the UNFCCC secretariat comprising individual CDM project information for all projects in the CDM pipeline[1] including among other information, project status, project specific data on the expected and issued CERs, the crediting period chosen, and time related data (e.g. project design document submission, registration, monitoring and issuance dates). The database is augmented with data from project design documents (PDDs) gathered in various capture campaigns starting in 2006 (such as technology transfer, sustainable development and financial parameters);
- Responses to an ongoing survey[2] of project participants concerning the sustainable development and technology transfer impacts of their projects;
- Published research on and analyses of the CDM and its impacts;
- The United Nations Environment Programme (UNEP) Risø Centre CDM pipeline as of June 2012.[3] These data were used to classify projects by their type (wind, hydro, etc.) and subtype (run-of-river, dam, etc.);
- The Institute for Global Environmental Strategies (IGES) CDM Project Database as of May 2012.[4] These data were used to establish the start dates of the CDM projects;
- Bloomberg new energy finance (BNEF) data as of May 2012 – a proprietary database of all major financing events related to specific renewable energy projects worldwide. The data include the asset value (capital investment) and capacity for individual projects by country by year of financial closure, the originating country of the investment, and type of finance (debt/equity).

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[1] The CDM pipeline is taken to be all projects for which a PDD containing a description of the proposed CDM project has been completed and made available for public comment.

[2] Available at: <https://www.research.net/s/unfccc>.

[3] The UNEP Risø Centre CDM Pipeline provides monthly updated data for most CDM projects. Available at: <http://www.cdmpipeline.org/>.

[4] The IGES Market Mechanism Group provides monthly updated data for most CDM projects. Available at: <http://www.iges.or.jp/en/cdm/index.html>.

This study is structured as follows. Section 2 summarizes the claimed contributions of CDM project activities[5] to sustainable development in their host countries. Section 3 highlights the transfer of technology via CDM projects. Section 4 provides estimates of finance and costs for various types of projects, and savings and revenue due to the use of CERs[6]. Section 5 examines the regional distribution of CDM projects. Finally, Section 6 discusses opportunities for improvement and further work.

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[5] Unless otherwise stated, for ease of exposition “projects” or “project activities” should be interpreted to exclude “programmes of activities”.

[6] This section draws on Spalding-Fecher et al., 2012.


Cab e
Antioqueño

# II. SUSTAINABLE DEVELOPMENT AND CDM PROJECTS

## 2.1. DEFINITION OF SUSTAINABLE DEVELOPMENT

The Brundtland Report, *Our Common Future*, defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.[7] It spawned an extensive body of literature on the concept of sustainable development as well as numerous attempts to measure whether specific actions contribute to sustainable development.

There is still no universally accepted definition of sustainable development or agreed basis for determining whether a specific action, such as a proposed CDM project, would contribute to sustainable development. However, it is widely agreed and was recently reiterated in the outcome of the Rio+ 20 conference[8] that sustainable development comprises three mutually reinforcing dimensions, namely economic development, social development, and environmental protection.[9]

Owing in part to the absence of an accepted international definition of sustainable development, the responsibility for determining whether a CDM project contributes to national sustainable development as defined by the host country currently resides with its designated national authority (DNA). The DNA therefore states in its letter of approval of the CDM project that, in its judgement, the proposed CDM project will contribute to the country’s sustainable development.[10] A Designated Operational Entity (DOE must ensure confirmation by the DNA of the host country that the project activity assists in achieving sustainable development in the host country.[11]

## 2.2. ASSESSING SUSTAINABLE DEVELOPMENT

Assessing the contribution of the CDM in assisting host countries in achieving sustainable development is challenging for the same reason – the lack of an agreed operational definition. Two types of assessment of the contribution of the CDM to sustainable development are possible on a project-by-project basis:

- *How* a CDM project contributes to sustainable development; and
- *How much* a CDM project contributes to sustainable development?[12]

To determine *how* a CDM project contributes to sustainable development requires only a list of sustainable development indicators against which a project is assessed to show the nature of its contribution.[13]*How much* a CDM project contributes to sustainable development in addition to the mitigation of greenhouse gas (GHG) emissions requires a list of indicators, a quantitative or qualitative measure for each indicator that can be used to score the project, and weights that allow the scores for the different indicators to be aggregated into an overall measure of the extent of the contribution to sustainable development. Only two studies – by Sutter and Parreño (2007) and Alexeew et al. (2010) – attempt such an assessment. They are summarized in Section 2.10 below.

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[7] World Commission on Environment and Development, 1987, p. 8.

[8] 2012A/CONF.216/L.1, United Nations, Rio de Janeiro, Brazil 20-22 June.

[9] Adams, 2006; Olsen, 2007; and Alexeew, et al., 2010.

[10] TERI, 2012, section 2.3, discusses the criteria used by DNAs to assess the contribution of CDM projects to sustainable development. Olsen and Fenhann, 2008, table 1, p. 2821, summarizes the approaches used by seven countries. Sterk et al., 2009, summarizes the sustainable development requirements of 15 DNAs using the Gold Standard as a basis.

[11] Decision 3/CMP.6, paragraph 40.

[12] Olsen and Fenhann, 2008, p. 2820.

[13] Olsen and Fenhann, 2008, use this approach.

## 2.3. INDICATORS OF SUSTAINABLE DEVELOPMENT

A list of sustainable development indicators is a requirement for both types of assessment. As yet there is no agreed list of indicators suitable for CDM projects. In this study a set of 10 indicators was derived from the statements made in the PDDs for registered CDM projects.[14] These indicators, presented in Table 1, cover the economic, environmental and social development dimensions of sustainable development. They encompass most of the criteria used by other studies.[15] The descriptions attempt to clearly distinguish the differences so that claimed benefits can be assessed consistently.

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[14] The UNFCCC 2011 study made use of 15 indicators. In this study the same indicators were merged or disaggregated into more discrete and appropriate indicators.

[15] Input from Luz Fernandez; Charlotte Unger; Alexeew, et al., 2010; Huq, 2002; Nussbaumer, 2009; Olsen and Fenhann, 2007; Sutter and Parreño 2007; and Sterk et al., 2009.

Table 1. **Sustainable development dimensions and indicators for clean development mechanism projects**

| Dimension | Indicator | Description |
|---|---|---|
| Economic | Stimulation of the local economy including job creation and poverty alleviation | Economic improvements for the population through: direct or indirect job creation or retention of jobs, during the operation and construction phases; domestic or community cost savings; poverty reduction; financial benefits of the project for the national economy of the host country; enhancement of local investment and tourism; improvement of trade balance for the country; reinvestment of clean development mechanism proceeds into the community; creation of tax revenue for the community |
| | Development and diffusion of technology | Development, use, improvement and/or diffusion of a new local or international technology, international technology transfer or development of an in-house innovative technology |
| | Improvement to infrastructure | Creation of infrastructure (e.g. roads and bridges) and improved service availability (e.g. health centres and water availability) |
| Environment | Reduction of pollution | Reducing gaseous emissions other than greenhouse gases, effluents, and odour and environmental and noise pollution; and enhancing indoor air quality |
| | Promotion of reliable and renewable energy | Supplying more or making less use of energy; stabilizing energy for the promotion of local enterprises; diversifying the sources of electricity generation |
| | | Converting or adding to the country's energy capacity that is generated from renewable sources; reducing dependence on fossil fuels; helping to stimulate the growth of the renewable power industries |
| | Preservation of natural resources | Promoting comprehensive utilization of the local natural resources (i.e. utilizing discarded biomass for energy rather than leaving it to decay, utilizing water and solar resources); promoting efficiency (e.g. compact fluorescent lamps rather than incandescent lamps); recycling; creating positive by-products; improvement and/or protection of natural resources, including the security of non-renewable resources such as fossil fuels, or of renewable resources such as: soil and soil fertility; biodiversity (e.g. genetic diversity, species, alteration or preservation of habitats existing within the project's impact boundaries and depletion level of renewable stocks like water, forests and fisheries); water, availability of water and water quality |
| Social | Improvement of health and safety | Improvements to health, safety and welfare of local people through a reduction in exposure to factors impacting health and safety, and/or changes that improve their lifestyles, especially for the poorest and most vulnerable members of society; improved human rights |
| | Engagement of local population | Community or local/regional involvement in decision-making; respect and consideration of the rights of local/indigenous people; promotion of social harmony; education and awareness of local environmental issues; professional training of unskilled workers; reduction of urban migration |
| | Promotion of education | Improved accessibility of educational resources (reducing time and energy spent by children in collecting firewood for cooking, having access to electricity to study at night, and supplementing other educational opportunities); donating resources for local education |
| | Empowerment of women, care of children and the frail | Provision of and improvements in access to education and training for young people and women; enhancement of the position of women and children in society |

The sustainable development claims in the PDDs of 3,864 projects registered and undergoing registration as at June 2012 were tabulated using the indicators in Table 1. Up to six indicators were assigned to each project, which was sufficient to cover all of the sustainable development claims. Project participants sometimes make more than six statements in the PDDs but one indicator is often sufficient to cover several statements made. For instance, the indicator "Stimulation of the local economy including job creation and poverty alleviation" can cover three or more statements made in a PDD[16].

A few (32) PDDs make no statement as to the project's contribution to sustainable development, while an even smaller number (8) make no specific sustainable development statements, but do, however, state that the project adheres to the host country's sustainable development criteria. As these projects had no specific statement which could attribute the project action to any of the indicators listed in Table 1, they were not included in the analysis of sustainable development.

### 2.3.1 Method and assumptions in assessing sustainable development

Assessing the statements from various sections of the PDDs[17] involves some subjectivity. To control this source of variance, the manner in which the data were collected used the following method and assumptions:

1. Different analysts using different assessment methods could place different emphasis on or assign different indicators to any given project.[18] To be as consistent as possible, all projects were assessed and assigned indicators by a single analyst.
2. The source of the data is the PDD; therefore only positive contributions to sustainable development were assessed since project developers never state anything negative about their projects.
3. No attempt was made to independently verify the sustainable development claims so statements made may not reflect the actual delivery of the claimed sustainable development benefit.
4. Claims of reduction in GHG emissions were not treated as sustainable development claims and were not part of the sustainable development indicators since this is a prerequisite for a CDM project.
5. "Non-negative" sustainable development claims such as "*the project will not lead to environmental degradation*" were not treated as sustainable development claims due to their imprecision.
6. General statements relating to the promotion of sustainable development in the host country, but not directly related to the project, were not treated as sustainable development claims due to a lack of specific attribution of the project action to any of the indicators listed in Table 1.

## 2.4. HOW CDM PROJECTS CONTRIBUTE TO SUSTAINABLE DEVELOPMENT

The indicators for 3,864 projects were used to describe *how* CDM projects claim to contribute to sustainable development (comprising an additional 1,614 projects to those in UNFCCC 2011[19]).[20] The indicators are based on information in the PDDs, which reflects the expected contributions at the time the project is being validated. The actual contributions may differ – an issue that is explored in Section 2.9 below.

Figure 1 shows the number of projects that mentioned each of the 10 indicators. The sustainable development contributions claimed most frequently are *stimulation to the local economy* including *job creation and poverty alleviation* (29 per cent of the projects), *reduction of pollution* (22 per cent of projects), and *promotion of reliable and renewable energy* (19 per cent of the projects). Although the percentages are very different, Olsen and Fenhann found a similar pattern: employment generation was the most likely impact, followed by contribution to economic growth and improved air quality.[21]

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[16] PPD´s were found to make a maximum of six statements, which could be related to the indicators in Table 1. 92 per cent of PDDs stated four or less indicators.

[17] Most information on sustainable development contributions is found in section A.2 of the PDD. "Description of the project activity", where the view of the project participants on the contribution of the project activity to sustainable development is requested (maximum one page).

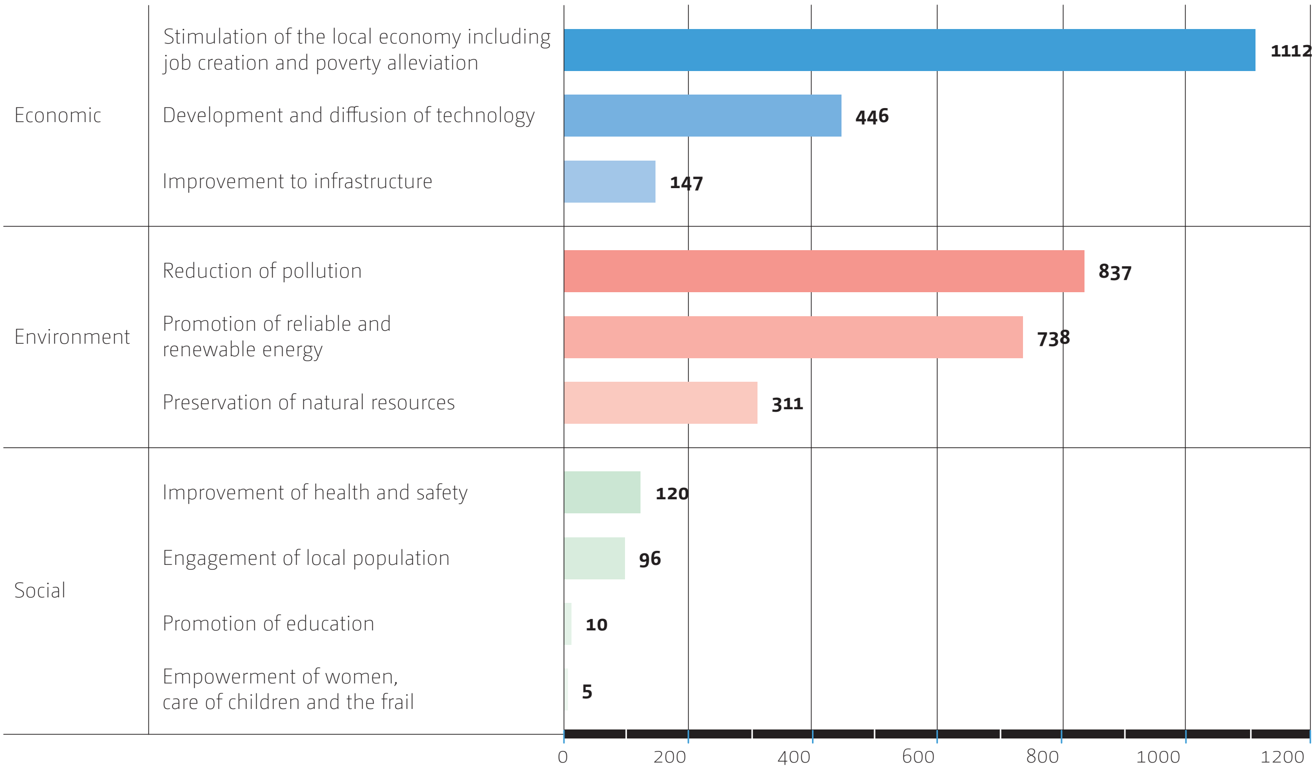
[18] Olsen and Fenhann, 2008, p. 2823.

[19] UNFCCC, 2011, p. 22. Several PDD's assessed in 2011 were revisited in 2012.

[20] So that the contribution of each project has the same weight, the indicators for each project have a total weight of 1 – if there is a single indicator, it is given a weight of 1, if there are two indicators each has a weight of 0.5, if there are three indicators they each have a weight of 0.333, and so on.

[21] Olsen and Fenhann, 2008, p. 2825, based on analysis of 296 projects in the pipeline as at 3 May 2006.

Figure 1. **Number of sustainable development claims by indicator**



Source: Based on statements in the PDDs for 3,864 projects registered and undergoing registration as of June 2012.

As shown in Figure 1, claims of environmental benefits (49 per cent of projects) and economic benefits (45 per cent of projects) far exceed those of social benefits (6 per cent of projects). In contrast, Olsen and Fenhann found the distribution of claimed benefits among the three dimensions to be fairly even, with the most benefits claimed in the social dimension, followed by the economic and environmental dimensions.[22]

## 2.5. SUSTAINABLE DEVELOPMENT CONTRIBUTIONS BY PROJECT TYPE

The sustainable development claims by project type are shown in Figure 2. The project type definitions are presented in Table A-1. Indicators in the economic dimension are shown in shades of blue on the left of the graph, environmental indicators in shades of red in the middle, and social indicators in green on the right. It is clear that the economic and environmental dimensions are dominant for most project types. The social dimension is most prominent for PFC and $SF_6$[23], $N_2O$, energy efficiency service, and landfill gas project mostly due to statements about how the project improves health and safety and, for $N_2O$ projects, engagement of the local population.

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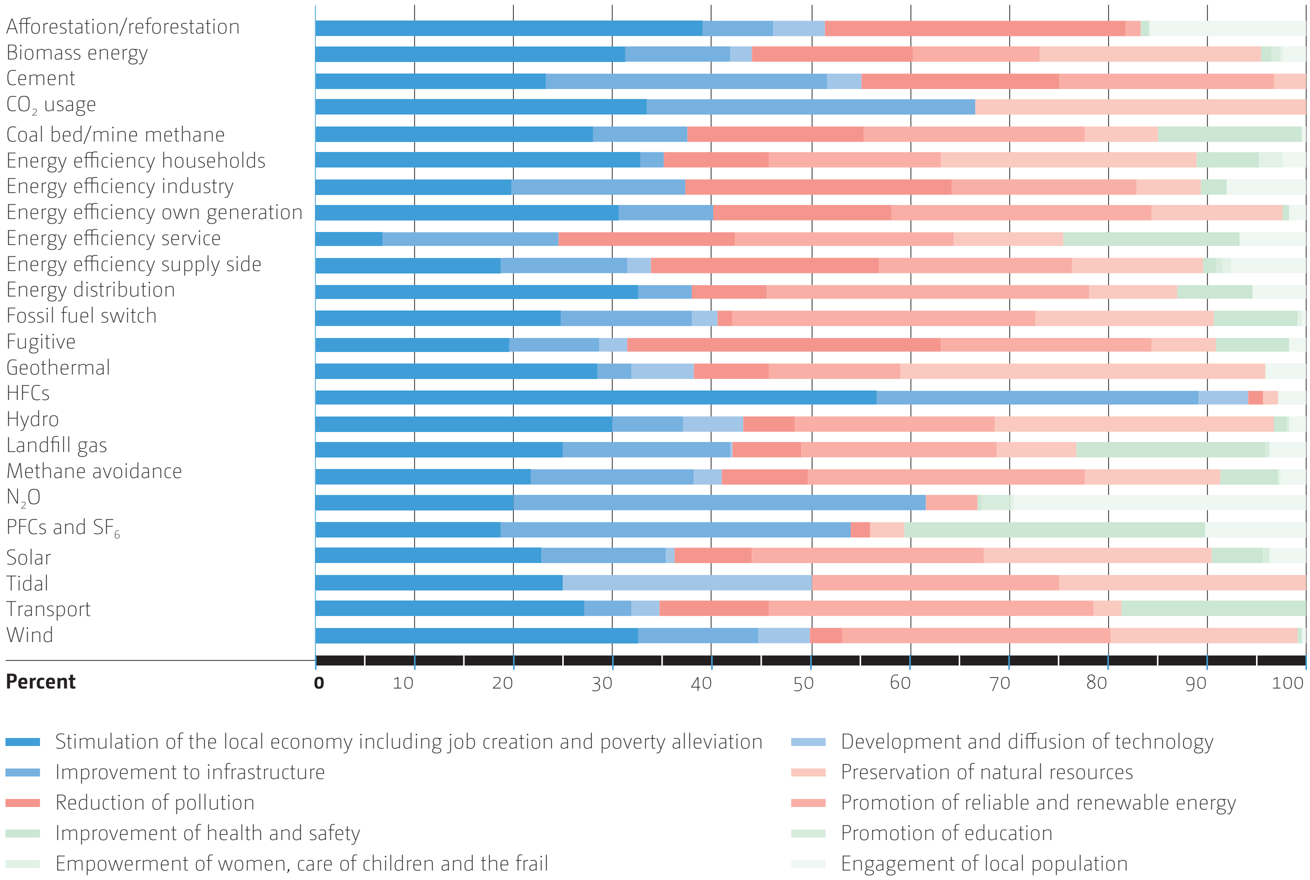
[22] Olsen and Fenhann, 2008, p. 2825. In some cases the distribution of claimed benefits among the three dimensions is not directly comparable. For instance, Olsen and Fenhann categorized employment as a social benefit, whereas it is categorized as an economic benefit here.

[23] For PFC and $SF_6$ projects, there are only 10 projects that make a sustainable development claim .

Figure 2. **Sustainable development claims by project type as a percentage of the total claims**



Source: Based on statements in the PDDs for 3,864 projects registered and undergoing registration as of June 2012.

Although almost all sustainable development indicators are claimed by most project types, similar projects tend to claim similar sustainable development contributions. HFC projects report the most economic sustainable development contributions and the highest levels of *stimulation to the local economy* including *job creation and poverty alleviation*. This indicator is claimed more often than any other indicator for all project types except energy efficiency industry, fossil fuel switch, methane avoidance, and $N_2O$. *Preservation of natural resources* is claimed more often for afforestation/reforestation, energy efficiency industry and fugitive projects.[24] In the social dimension, *Improvement of health and safety* seems to be reported more often for coal bed/mine methane, energy efficiency own generation and landfill gas projects, owing in part to safer working conditions due to lower risk of explosions from methane leakage. The PFCs and $SF_6$ project type claim *improvement of health and safety* more often, but there are only a few projects of this type.

## 2.6. SUSTAINABLE DEVELOPMENT CONTRIBUTIONS BY HOST COUNTRY

The distribution of sustainable development claims by host country is shown in Figure 3 for the 10 countries with the most registered projects and for all other host countries combined. As per the chart above, the economic indicators are shown in shades of blue on the left, the environmental indicators in shades of red in the middle, and the social indicators in green on the right. Since the 10 are countries with a relatively large number of projects and also of a mix of project types, it is to be expected that the projects they host claim almost all sustainable development contributions. Projects in each of the host countries cite at least eight of the 10 sustainable development indicators. No single indicator is prominent in the 10 largest CDM project host countries.

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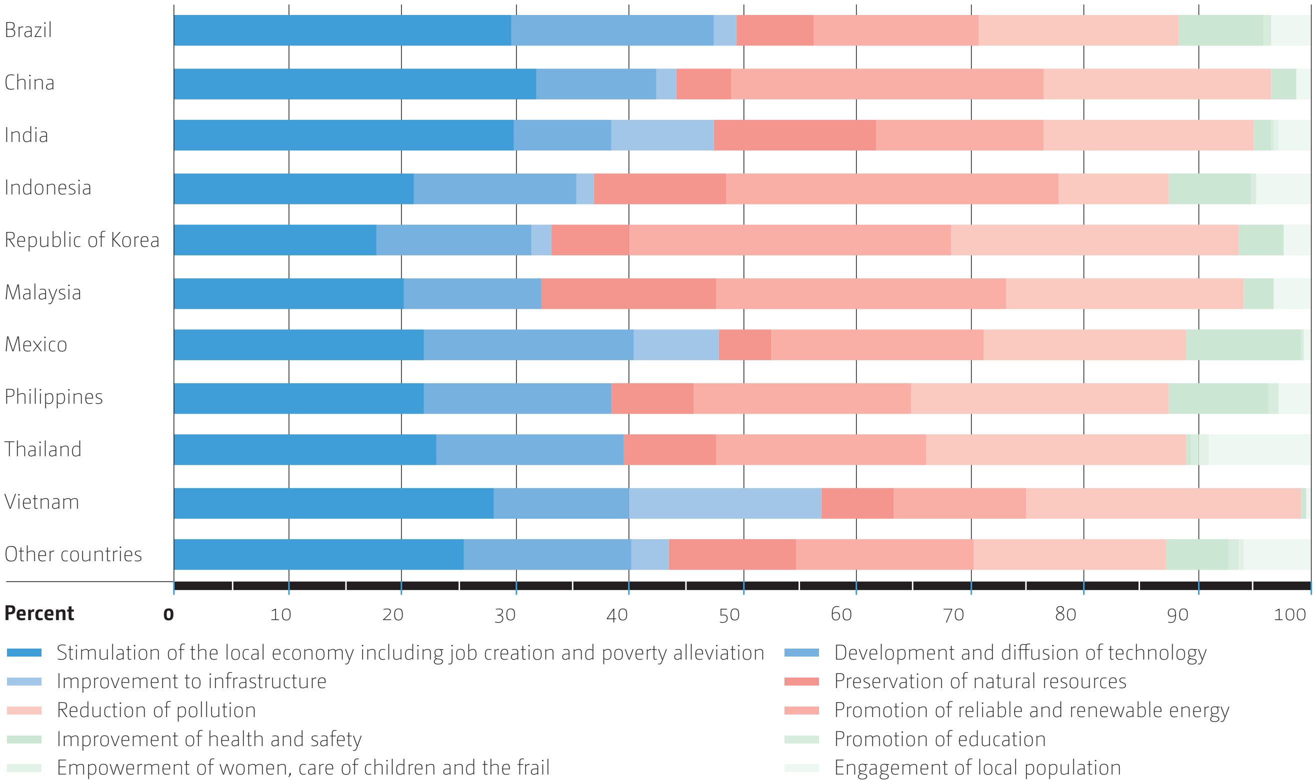
[24] Many project participants refer to the preservation of fossil fuels when they claim the *preservation of natural resources*.

It is noteworthy that although the sustainable development indicators differ between countries, the overall proportions of the dimensions between countries are the same. In other words economic contributions are claimed more often than the others even though Malaysia, the Philippines and Thailand make no claims of *improvement to infrastructure*. The social contributions are consistently cited less often than the economic and environmental indicators in all countries. This also indicates the relative emphasis various countries place on different aspects of sustainable development, which tend to be predominantly economic in nature.

Figure 3. **Sustainable development claims as a percentage of the total claims by host country**

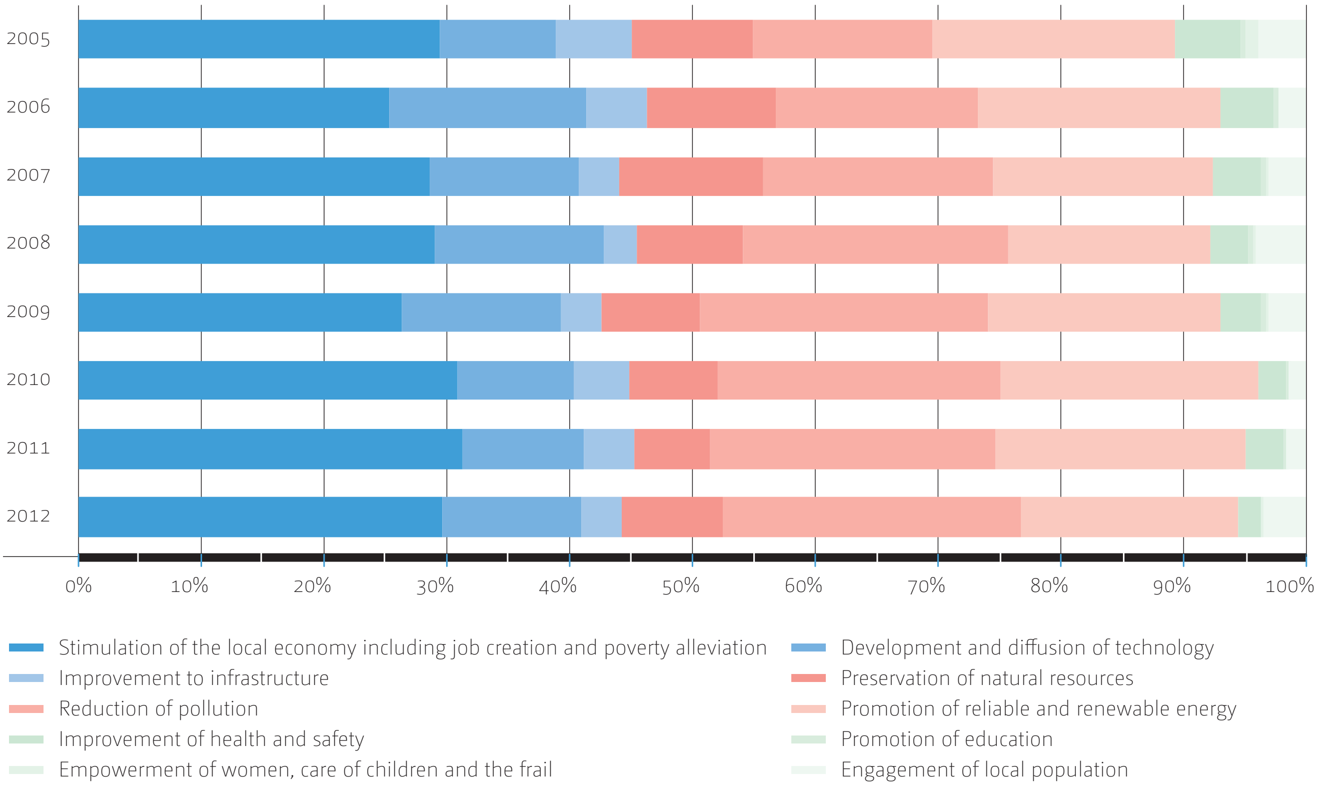


Source: Based on statements in the PDDs for 3,864 projects registered and undergoing registration as of June 2012.

## 2.7. TRENDS IN SUSTAINABLE DEVELOPMENT CONTRIBUTIONS

The distribution of sustainable development claims for projects by the year the CDM Executive Board registered the project is shown in Figure 4. The year 2004 is excluded as there were only four projects with data. The economic indicators have remained relatively constant over time but *stimulation of the local economy* including *job creation and poverty alleviation* has fluctuated slightly dropping as low as 26 per cent of all claims in 2006 and climbing as high as 31 per cent in 2011. *Reduction of pollution* claims have increased from 15 per cent of all claims in 2005 to 24 per cent in 2012, and social claims have fallen from 11 per cent to 6 per cent over the same time span.

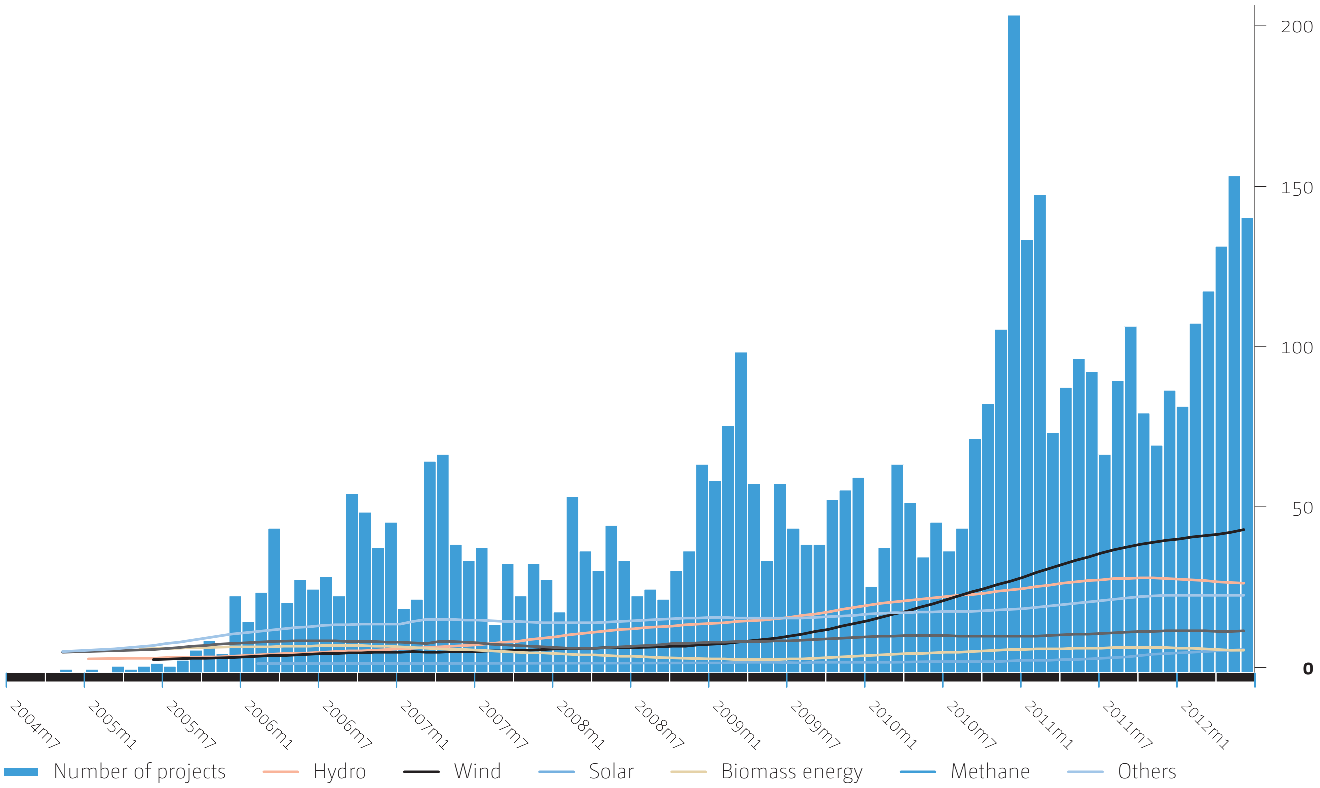
Figure 4. **Sustainable development claims as a percentage of the total claims by year project entered pipeline**



Source: Based on statements in the PDDs for 3,864 projects registered and undergoing registration as of April 2012.

These trends may be due to shifting patterns of sustainable development claims over time or changes in the project mix each year. As can be seen in Figure 5, biomass projects were prominent in 2005 but have declined since 2007. Wind and hydro projects, on the other hand, have increased exponentially since 2011.

Figure 5. **Trend in the type of project registered and undergoing registration**



## 2.8. COMPARISON OF CLAIMS IN PROJECT DESIGN DOCUMENTS AND SURVEY RESPONSES

PDD statements about contributions to sustainable development are expectations at the time the project is being validated. The actual sustainable development contributions therefore may be different. The United Nations Climate Change secretariat conducted a survey of project participants after projects had been registered in 2011 to assess each project's contribution to sustainable development. The survey attracted responses from 392 projects of which 332[25] overlapped with the projects for which data were recorded from PDDs.[26] The survey responses were compared with the indicators compiled from the PDDs.

Table 2 shows the percentage of the survey response indicators that match the indicators obtained from the PDD for the same projects.[27] For 8 per cent of the projects, none of the indicators from the PDD and the survey responses match. For 30 per cent of the projects, half the indicators from the two sources match. For 63 per cent of the projects at least half of the indicators matched. The survey responses and the indicators from the PDD´s are identical (100 per cent match) for nine of the 332 projects.

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[25] Due to different indicators used in this study, the total number of matches is slightly (4) lower than in UNFCCC 2011.

[26] Approximately 7 per cent of the projects (29) were assessed by up to four different respondents, who provided slightly different assessments of the contribution of the same project to sustainable development.

[27] For the 29 projects with multiple survey responses, an average response was calculated and used for the comparison.

Table 2. **Comparison of sustainable development indicators from project design documents and survey responses**

| Percentage match between survey and PDD indicators | Number of projects | Percentage of projects | Cumulative percentage |
|---:|---:|---:|---:|
| 0% | 27 | 8% | 100% |
| 25% | 33 | 10% | 92% |
| 33% | 64 | 19% | 82% |
| 50% | 100 | 30% | 63% |
| 67% | 82 | 25% | 33% |
| 75% | 17 | 5% | 8% |
| 100% | 9 | 3% | 3% |
|  | 332 | 100% |  |

Considering that both the survey and the PDDs have up to 10 indicators, the choice of which could vary from the time the PDD was drafted and the project implemented, that upwards of two-thirds of projects have similar sustainable development claims indicates that some claims made in the PDDs are reasonable representations of the sustainable development contributions expected by project participants. The lack of perfect agreement may be due to differences in judgment or interpretation concerning the applicable indicator or changes to the project's stated sustainable development contributions.

The developer of a Gold Standard[28] project is required to submit a sustainability monitoring plan in addition to the sustainable development assessment in the PDD. The monitoring plan is used to verify whether the CDM project has indeed contributed to sustainable development as anticipated in the PDD. This may cause the project developer to consider the impacts of the project carefully.[29] It may also create an incentive to keep the PDD analysis brief to minimize the monitoring requirements. The survey responses in Table 2 include responses in relation to 19 Gold Standard projects. The Gold Standard projects have approximately the same number of sustainable development indicators as non-certified CDM projects and the match between the survey and PDD indicators is the same as for non-certified CDM projects.[30]

## 2.9. OTHER STUDIES ON THE SUSTAINABLE DEVELOPMENT CONTRIBUTIONS OF THE CDM

Since the Kyoto Protocol entered into force in early 2005, the sustainable development contributions of the CDM have been the subject of extensive commentary and research in the academic literature.

Olsen (2007) reviewed 19 studies that focused on sustainable development aspects of the CDM available as at June 2005. None of the studies assessed registered CDM projects, although some analysed projects similar to CDM projects. Olsen concluded that, at the time, a consensus was emerging that the CDM produces low-cost emission reductions at the expense of achieving sustainable development benefits.

[28] See <http://www.cdmgoldstandard.org/>

[29] Sterk et al., 2009, p. 16.

[30] The data for Gold Standard projects are not reported separately here.

Sutter and Parreño (2007) applied multi-attribute utility theory[31] to assess the sustainable development contribution of the first 16 registered CDM projects.[32] Each project was scored on three equally weighted criteria – employment generation, distribution of returns from the sale of CERs, and improved local air quality – to get an overall score for its contribution to sustainable development. Also the additionality of each project was measured by the effect of the revenue from the sale of CERs on the project's profitability; the larger the increase, the greater the additionality of the project. Projects were then categorized as making a large or small contribution to sustainable development and having low or high additionality. Sutter and Parreño found no projects that made a large contribution to sustainable development and were highly additional.[33] Most of the emission reductions (over 95 per cent) came from HFC and landfill gas projects that were highly additional but made a small contribution to sustainable development. They concluded that the first 16 registered CDM projects may have been far from delivering their claims to promote sustainable development although this conclusion could have changed with different indicators and weights.[34]

In response to concerns about the sustainable development contribution of CDM projects, several initiatives, including the Gold Standard and the Community Development Carbon Fund (CDCF)[35] were launched to support projects that meet specific sustainable development criteria. The Gold Standard label rewards best-practice CDM projects while the CDCF focuses on promoting CDM activities in underprivileged communities. Nussbaumer (2009) used multi-criteria analysis to compare the sustainable development contributions of Gold Standard, CDCF and regular CDM projects. He applied 12 sustainable development criteria to 39 projects in 10 categories located in 12 countries.[36]

Nussbaumer found that the sustainable development profiles of Gold Standard and CDCF projects tend to be comparable with or slightly more ample than similar regular projects.[37] The Gold Standard and CDCF projects performed better with respect to social criteria while regular CDM projects perform better on economic criteria. Overall, Nussbaumer concluded that "labeled projects do not drastically outperform non-labeled ones", however the differences in the sustainable development performance of comparable categories of projects might be within the range of uncertainty intrinsic to such assessments.

The sustainable development claims of a random sample of 409 projects in the pipeline as of October 2008 were analysed by Watson and Fankhauser (2009). Benefits expected to occur in all projects, such as GHG reductions, and negative impacts were not counted. The frequency of the claims for the eight indicators analysed was employment (82%), training (67%), technology transfer (33%), livelihood benefits (23%), pollution reduction (21%), infrastructure building (21%), education (5%) and environmental benefits (4%). HFC, PFC, and $N_2O$ reduction projects were found to have less sustainable development benefits than renewable energy or forestry projects.

Alexeew et al. (2010) applied a methodology similar to that used by Sutter and Parreño (2007) to assess the contribution to sustainable development and the additionality of 40 registered projects in India.[38] Contribution to sustainable development was assessed using 11 criteria – four social, four economic and three environmental. A project was given a score of between –1 and +1 for each criterion. The scores were summed – the criteria were weighted equally – to get an overall score for each project. Additionality was measured by the impact of the revenue from the sale of CERs on the project's profitability.

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[31] CDM projects were assessed with respect to multiple attributes (indicators), and the scores for the different attributes were weighted and aggregated to arrive at an overall assessment.

[32] The 16 projects cover seven project types – six hydro projects, three landfill gas projects, two biomass projects, two HFC-23 destruction projects and one project each for residential energy efficiency, fossil fuel switch and wind – in nine host countries.

[33] The paper includes conflicting information on this conclusion. Figure 3 and the text (p. 87) indicate that there are no projects with a high rating for both additionality and sustainable development. But Table 17 reports that two projects accounting for 0.1 per cent of the projected emission reductions for the 16 projects have both high additionality and a high contribution to sustainable development.

[34] Sutter and Parreño, 2007, p. 89.

[35] See < http://wbcarbonfinance.org/>

[36] The 12 sustainable development criteria consist of four each for the social, economic and environmental dimensions. The criteria are not aggregated or weighted. The project categories are: biogas (thermal): (four projects); industrial energy efficiency: (six); landfill gas: (three); biomass: (three); biogas (electricity generation): (three); building energy efficiency: (three); hydro (run of river): (six); hydro (new dam): (three); wind: (six) and solar cooking: (two). Ten of the projects are CDCF, six are Gold Standard and 23 are regular CDM projects. Seventeen projects are located in India, eight in China, two each in Argentina, Honduras, Republic of Moldova and Nepal, and one each in Chile, Indonesia, Mexico, Panama, Peru and South Africa.

[37] Nussbaumer, 2009, p. 99. A project's profile is its scores for the 12 sustainable development indicators.

[38] The 40 projects are a sample of the 379 that had been registered by 31December 2008. They include 15 biomass, 12 wind, seven hydro, four energy efficiency and two HFC-23 destruction projects. Nine are regular CDM projects and 31 are small scale-projects.

The sustainable development scores for individual projects range between 2 and 5.6 out of a possible range of –11 to +11. The values for each dimension of sustainability differ significantly across project types. Wind, hydro and biomass projects provide a relatively high number of sustainable development benefits. Energy efficiency and particularly HFC-23 projects did not contribute to sustainable development as the other kinds of projects.[39] Projects are categorized as making a large or small contribution to sustainable development and having low or high additionality. None of the projects both make a large contribution to sustainable development and have high additionality.[40]

In a detailed study of 10 CDM projects Boyd, et. al. (2009) found that it can be misleading to assess a project´s sustainable development outcomes only through the project documentation as local conditions change or are not declared due to either a lack of understanding of possible contributions or by intentional omission of critical views and opinions.[41]

The sustainable development claims of 122 projects in China, India, Brazil, Peru, Malaysia and South Africa were assessed using 15 criteria by Disch (2010). These countries face different challenges, have different priorities and are at different stages of development, and thus use different approaches to assessing the sustainable development contributions of proposed CDM projects. Disch concluded that the host countries' frameworks for CDM project approval, except in the case of Peru, fall short of ensuring a sustainable development benefit. Peru takes a distinct approach including stakeholder involvement and on-site visits, to confirm a projects' contribution to sustainable development.

Lee and Lazarus (2011) evaluated the potential for sustainable development benefits for 77 projects covering 12 bioenergy project types. Projects were evaluated against 15 sustainable development criteria using text analysis software reviews of their PDDs.[42] The most common benefits claimed were renewable energy production (100%), stakeholder consultation (99%), waste reduction (82%), employment generation (60%), and indirect income generation through local sourcing of feedstock (57%). The sustainable development benefits claimed differ as widely among bioenergy project types as among all other CDM project types. Bioenergy projects that rely on on-farm residues claim to offer the greatest number of benefits while those that rely on industrial forestry residues claim the fewest.

Subbarao and Lloyd (2011) analysed the sustainable development claims in the PDDs of 500 registered small-scale projects. The projects were mainly (nearly 90%) renewable and energy efficiency, such as biomass energy, methane recovery, micro/small hydro and solar cookers. Projects were scored on 10 criteria with values from -1 to +2. The average score for all of the criteria, except impacts on local resources, was close to zero. Thus the authors concluded that local communities have not benefited significantly from the small-scale CDM projects.

Using the Human Development Index (HDI) as a measure of sustainable development, Huang et al. (2012a) analysed CDM activity and HDI values for 58 host countries for the period 2005 through 2010.[43] They found that a higher host country HDI is associated with more CERs per capita, a higher ratio of CERs per dollar of GDP, a larger share of CERs relative to total emissions, and a higher ratio of CDM investment per dollar of GDP. The causality is not clear; CDM projects may contribute to the host country's sustainable development or countries with better economic and social development may attract more CDM projects.

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[39] Alexeew et al., 2010, p. 12.

[40] Alexeew et al., 2010, figure 4, p. 11. This is consistent with Sutter and Parreño (2007). Unlike Sutter and Parreño, Alexeew et al. found that most projects make a large sustainable development contribution. That may be due to the project mix. Alexeew et al. (2010) assessed 15 biomass and seven hydro projects (out of 40) – project types that Sutter and Parreño also found to make a large contribution to sustainable development.

[41] This is consistent with the comparison of sustainable development indicators compiled from PDDs and those from survey responses for the same project discussed in Section 2.9 above.

[42] The 15 criteria are the same as those used by Disch (2010).

[43] The HDI is an index of life expectancy, literacy, education and standard of living. It does not include changes to the environment.

## 2.10. SUMMARY

Since the registration of the first CDM project in 2004, scholars and policymakers alike have attempted to understand how the CDM contributes to sustainable development. All of the studies rely mainly on information provided in project design documents and they use different indicators of sustainable development. A positive impact with benefits distributed across economic, environmental, and social areas is claimed for all project types. Some studies claim that hydrofluorocarbon (HFC) and nitrous oxide ($N_2O$) projects yield the fewest sustainable development benefits. Other studies suggest a trade-off in favour of producing low-cost emission reductions at the expense of achieving sustainable development.

This study assesses the claims made by project participants in the project design documents submitted for registration. The relative reliability of these claims, as verified by a follow-up survey, suggests that the CDM is making a contribution to sustainable development in host countries in addition to the mitigation of greenhouse gas (GHG) emissions. Almost all CDM projects claim multiple sustainable development benefits, but the mix of benefits claimed varies considerably by project type.

The most prominent benefit claimed is stimulation of the local economy through employment creation and poverty alleviation, followed by reduction of pollution and promotion of renewable energy and energy access. The mix of benefits claimed has not changed significantly since the first CDM project was registered, except that claims of environmental and noise pollution reduction have become more common.

Under the CDM modalities and procedures, each non-Annex I Party (host country) has the authority to assess whether a CDM project contributes to sustainable development according to national development priorities. A comparison of projects across different countries shows that the host country has an effect on the mix of benefits claimed by a project. However, social benefits tend to be cited (or possibly required of projects) less often than economic and environmental benefits in all countries.

There is room for improvement in both the standards and approaches used for the declaration of sustainable development of CDM projects, as confirmed by many other studies. It should be noted that some of the conclusions from these other studies are based on extremely small sample sizes. Despite the lack of precision in the definition and understanding of sustainable development, it can be concluded that the occurrence of certain claims that include environmental and social considerations (such as the *preservation of natural resources*, the *reduction of pollution*, the *promotion of reliable and renewable energy*, and the *improvement of health and safety*) are almost always solely attributed to the CDM project and would not have occurred in its absence. However, it is less clear whether the claimed economic benefits would have occurred regardless of the CDM project. For instance, many of the renewable energy CDM projects state the addition of fossil fuel generation capacity as an option in the baseline. Despite possible environmental implications, the baseline scenario can nevertheless contribute to the *stimulation to the local economy* including *job creation and poverty alleviation*, to the *development and diffusion of technology*, and to the *improvement to infrastructure*. As such, the economic contribution of CDM projects requires more precise data on both the project and baseline scenarios.

# III. TECHNOLOGY TRANSFER VIA CDM PROJECTS

Transfer of technology is an important benefit of the CDM, assisting developing countries in reducing GHG emissions and achieving sustainable development. Some host countries explicitly specify technology requirements, including technology transfer, as a requirement for approval of a project.[44] Most GHG mitigation technologies originate in developed countries.[45] To reduce emissions in developing countries the appropriate technologies need to be transferred to those countries.[46] The CDM is one means by which mitigation technologies can be transferred; others include licensing, foreign direct investment, trade and, more recently, establishment of global research and development networks, acquisition of firms in developed countries, and recruitment by firms in developing countries of experts from developed countries.

## 3.1. DEFINITION OF TECHNOLOGY TRANSFER

There is no universally accepted definition of technology transfer.[47] The Intergovernmental Panel on Climate Change (IPCC) defines technology transfer as “a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private-sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions”.[48]This definition covers every relevant flow of hardware, software, information and knowledge between and within countries, from developed to developing countries and vice versa whether on commercial terms or on a preferential basis. The IPCC acknowledges that “the treatment of technology transfer in this report is much broader than that in the UNFCCC or of any particular Article of that Convention”.[49] In particular, the Convention and the CDM, as an international mechanism, focus on international transfers of technology.

Transfer of knowledge, not just equipment, is an important aspect of technology transfer. The United Nations Conference on Trade and Development (UNCTAD) excludes the mere sale or lease of goods from technology transfer.[50] Equipment that embodies a technology new to a country must be accompanied by transfer of sufficient knowledge to successfully install, operate and maintain the equipment.

The survey conducted by the secretariat in 2011 asked respondents for their view on when an organization can state it ‘has’ a technology.[51] A significant majority of respondents, (68 per cent) indicated that it is when an organization uses and has knowledge of the technology. Simply using a technology (20 per cent) or having knowledge of a technology (10 per cent) is not sufficient. Thus, the views of most respondents are consistent with the the UNCTAD definition and the literature.[52]

Whether technology transfer also requires that the recipient country be able to adapt the technology to local conditions, to produce similar equipment domestically, or to further develop the technology is debated in the literature.[53] Technology transfer induced by the CDM naturally will focus on meeting the technology needs of the projects. In most cases those needs can be met with imported equipment and/or knowledge. Creation of capacity in the recipient country to adapt, produce or further develop the technology is likely to be rare.[54]

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[44] TERI, 2012, Section 4.3.

[45] Johnstone, et al., 2010., and Sterk et al., 2009

[46] The technologies may need to be adapted to developing countries’ conditions, and technologies may need to be developed to mitigate emissions from sources found predominantly in developing countries.

[47] Cools, 2007; Popp, 2011, p. 136; and Das 2011.

[48] IPCC, 2000, p. 3.

[49] IPCC, 2000, p. 3.

[50] UNCTAD, 1985, chapter 1, paragraph 1.2.

[51] To assist respondents the survey defines the terms as follows: technology – could include equipment, machinery, tools, techniques, crafts, systems or methods of organization; use – could include owning and/or operating equipment or processes that use the technology; and knowledge – could include shared or exclusive participation in patents, licences, training programmes, academic papers, etc. relating to the technology.

[52] Foray, 2009; Lall, 1993; and Popp, 2011.

[53] Das (2011) defines three types of technology transfer; III –technology import, II – import with local adaptation or improvement, and I - host country development of a technology. The analysis of the PDDs for 1,000 registered projects found 259 with Type III, 6 with Type II and 0 with Type I technology transfer. However, as discussed in section 3.6 below, the PDDs understate the extent of technology transfer.

[54] Virtually every country has the capacity to operate and maintain electricity generating equipment, but electricity generating equipment of any given type – coal, oil, natural gas, nuclear, hydro, wind, solar, geothermal, etc. – is manufactured by a relatively small number of countries and the development of the generating technology occurs in even fewer countries.

International transfer of technology is unlikely if the technology is already available in the recipient country. Thus, technology transfer via CDM projects is likely to occur less frequently for mature technologies already widely available in developing countries, such as hydroelectric generation and cement production. Technology development and transfer can happen relatively quickly,[55] so the frequency and type of technology transfer via CDM projects is likely to change over time.

## 3.2. TECHNOLOGY TRANSFER CLAIMS OF CDM PROJECTS

CDM project participants are requested to "include a description of how environmentally safe and sound technology and know-how to be used is transferred to the host Party(ies)" in the PDD.[56] Claims of technology transfer made by project participants in the PDD are generally explicit enough to be used for technology transfer assessment. The claims made in the PDDs for 3,949 CDM projects registered and undergoing registration in 71 host countries up to June 2012 (comprising an additional 717 projects to those in UNFCCC 2011[57]) were tabulated and analysed.

As in the previous study (UNFCCC, 2011), each PDD is searched using a number of keywords to ensure that all statements relating to technology transfer are identified.[58] The statements are tabulated under the following categories:

- The project is expected to use imported equipment;
- The project is expected to use imported knowledge;
- The project is expected to use imported equipment and knowledge;
- It is stated that the project will not involve technology transfer;
- There are no statements with respect to technology transfer;
- Other statements relating to technology transfer.

It can be inferred from the statements in the PDDs that project participants overwhelmingly interpret technology transfer by the CDM project to mean equipment new to a country accompanied by transfer of sufficient knowledge to successfully install, operate and maintain the equipment.[59]

Technology transfer-related statements in the PDD reflect expectations at the time the project is being validated. The actual nature and frequency of technology transfer may differ, as discussed in Section 3.6 below.

## 3.3. TECHNOLOGY TRANSFER BY PROJECT TYPE

Project characteristics and the frequency of technology transfer – by number of projects and share of expected annual emission reductions – are shown in Figure 6 and Table A-2 by project type.[60] Of the projects that make an explicit claim regarding technology transfer – either that they do or do not involve technology transfer – 39 per cent representing 59 per cent of the total estimated annual emission reductions claim technology transfer. These results are consistent with previous UNFCCC studies.[61]

The PDDs of 18 per cent of the projects made no explicit statement concerning technology transfer. The percentages reported above exclude those projects.[62] As discussed in Section 3.6, most projects that make no statements relating to technology transfer actually involve technology transfer. Studies that express the number of projects that claim technology transfer as a percentage of all CDM projects reviewed implicitly assume that no statement relating to technology transfer means no technology transfer. Thus those studies understate the true rate of technology transfer.[63]

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[55] Johnstone, et al., 2010.

[56] UNFCCC, 2008, p. 8. TERI, 2012, p. 70 notes that the PDD format and technology transfer reporting requirement have changed over time.

[57] UNFCCC, 2011, p. 22.

[58] Keywords included technology, transfer, import, foreign, abroad, overseas, domestic, and indigenous.

[59] A small number of projects claim transfer of technology within the host country. These projects are assessed as not involving (international) technology transfer.

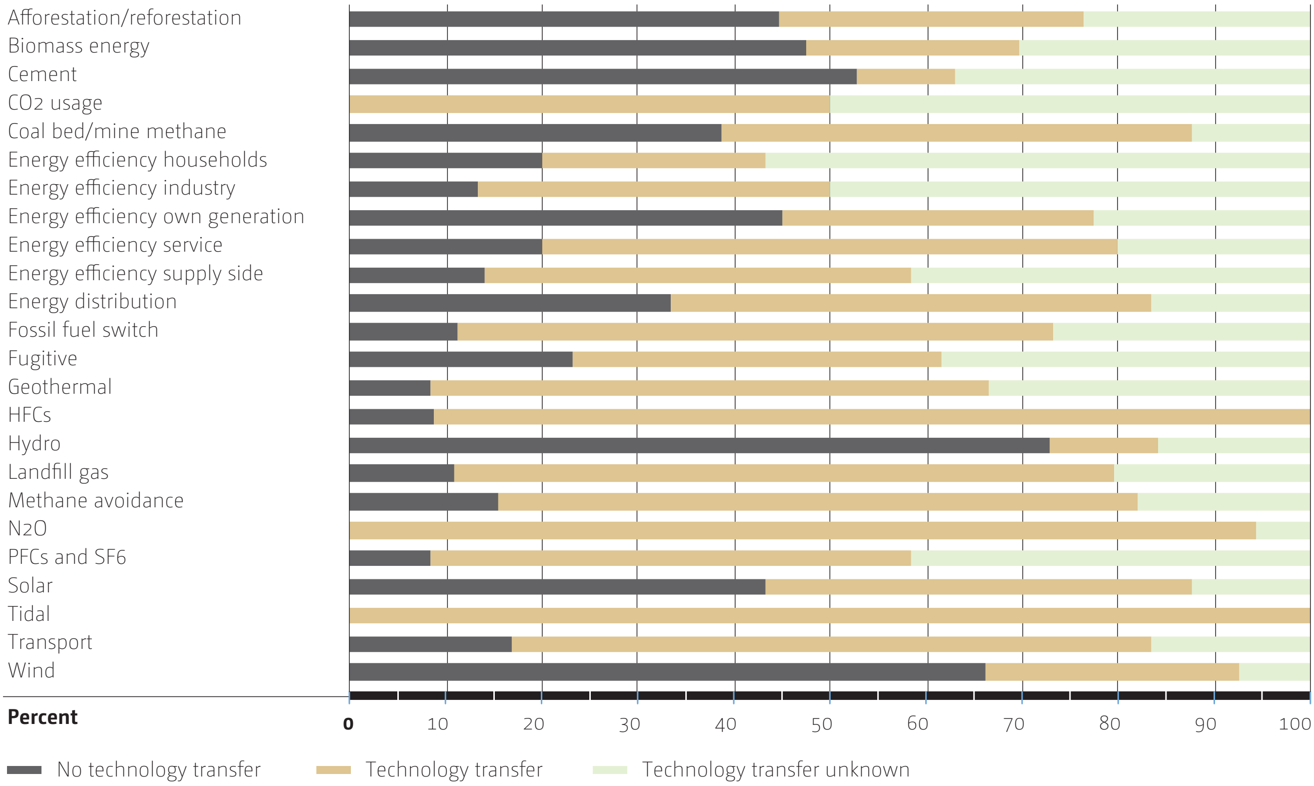
[60] See Table A-1 for definitions of the project types.

[61] UNFCCC, 2010, table IV-2, p. 19 shows corresponding figures of 40 per cent and 59 per cent respectively for 4,984 projects in the pipeline (projects registered, undergoing registration and undergoing validation) as of 30 June 2010. UNFCCC, 2011, table VII-10, p. 43 shows corresponding figures of 42 per cent and 64 per cent respectively for 3,232 registered projects as of 30 June 2011.

[62] This understates the frequency of technology transfer because 70 per cent of these projects involve technology transfer.

[63] Haites et al., 2006 and Das 2011, for example.

Figure 6. **Technology transfer by project type as a percentage of total registered projects**



Source: Based on statements in the PDDs for 3,949 projects registered and undergoing registration as of June 2012.

As anticipated, the distribution of technology transfer claims by project type is similar to that in UNFCCC 2011[64], with a slight difference in transport projects. In UNFCCC 2011[65] more than 40 per cent of projects claimed technology transfer and for the remainder it was unknown. This study shows that 67 per cent of projects claim a transfer of technology, 17 per cent say they will use domestic technology and the source of the technology is unknown for 16 per cent of projects. Wind projects also show a slight change compared to UNFCCC 2011. Sixty-six per cent of wind projects claim use of domestic technology versus 57 per cent in UNFCCC 2011. Afforestation and reforestation projects have been combined and show similar patterns to UNFCCC 2011.

On average, technology transfer is more common for larger projects. This holds true by project type with the exception of afforestation/reforestation, energy distribution, solar and hydro projects. As expected, the rate of technology transfer is lowest for hydro and cement projects, which are mature technologies that are widely available in developing countries.

## 3.4. TECHNOLOGY TRANSFER BY HOST COUNTRY

The rate of technology transfer by host country is presented in Table 3 for the 10 host countries with the most projects and all other host countries combined. The results are similar to those reported in the 2011 study with one difference: the percentages of technology transfer claims are calculated slightly differently than in past studies. The percentages are now based on the number of projects where technology transfer is known rather than all projects, to be consistent with other tables and graphs in this study.[66] As a result, the percentages in this study are higher than in the past.

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[64] UNFCCC, 2011, table VII-10, p. 43

[65] UNFCCC, 2011, p. 18

[66] Specifically, the percentages are calculated using only projects that specifically claim they involve or will not involve technology transfer; projects that make no statement relating to technology transfer are excluded.

Table 3. **Technology transfer for projects registered and undergoing registration in selected host countries**

| Country | Number of projects | Estimated emission reductions ($CO_2$ e / year) | Average project size ($CO_2$ e / year) | Technology transfer claims as a percentage of: Number of projects | Technology transfer claims as a percentage of: Annual emission reductions | Percentage of projects where technology transfer could not be determined |
|---|---|---|---|---|---|---|
| Brazil | 205 | 24,175,021 | 117,927 | 47% | 76% | 25% |
| China | 1858 | 367,754,013 | 197,930 | 20% | 49% | 6% |
| India | 805 | 67,474,383 | 83,819 | 23% | 53% | 34% |
| Indonesia | 80 | 8,308,580 | 103,857 | 95% | 79% | 31% |
| Malaysia | 110 | 6,293,316 | 57,212 | 90% | 94% | 36% |
| Mexico | 140 | 12,520,350 | 89,431 | 98% | 99% | 9% |
| Philippines | 57 | 2,238,466 | 39,271 | 59% | 87% | 14% |
| Rep. of Korea | 63 | 18,187,041 | 288,683 | 85% | 99% | 35% |
| Thailand | 67 | 3,541,395 | 52,857 | 100% | 100% | 16% |
| Vietnam | 90 | 5,410,299 | 60,114 | 96% | 83% | 17% |
| All other countries | 474 | 67,520,169 | 142,448 | 91% | 97% | 28% |
| **Total** | **3949** | **583,423,033** | **147,739** | **39%** | **59%** | **18%** |

Source: Based on data provided in the PDDs for 3,949 projects registered or undergoing registration as of June 2012. Percentages of technology transfer claims are based on 3,249 projects where claims could be determined.

With the exception of China, India, and to a lesser extent Brazil, technology transfer is claimed for a high proportion of projects. It is clear that due to the large number of projects in these three countries and their relatively low rates of technology transfer, the overall averages are being driven down by these countries.

Again, technology transfer claims are, on average, more common for larger projects with the exception of Indonesia and Vietnam where technology transfer seems to be less common for larger projects.

## 3.5. TREND IN TECHNOLOGY TRANSFER

The rate of technology transfer has declined over the life of the CDM as shown in Figure 7.[67] The decline has been steeper in China than the overall average, relatively less steep in India, while Brazil's rate of technology transfer has resembled the overall average.[68] Initially, China had a rate of technology transfer higher than the average for all countries, but the rate is now substantially lower. India has consistently had a rate of technology transfer lower than the average for all countries. The rate of technology transfer for other host countries has been much higher than the overall average and has declined only slightly.

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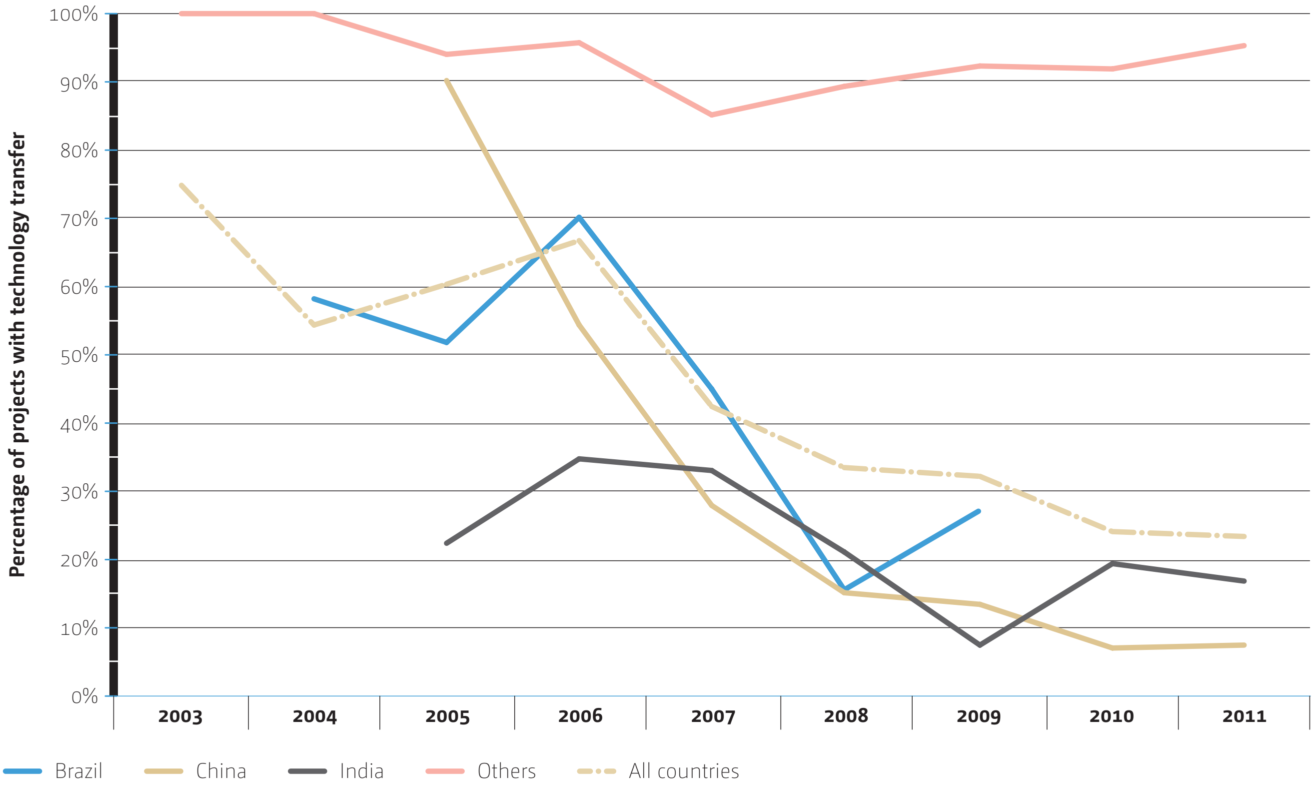
[67] The data in Figure 7 are by number of projects and the year in which each project is registered. The decline is larger when measured in terms of estimated annual emission reductions. The year chosen for this graph is the year the project entered the pipeline. As such, the actual transfer of technology may not take place until a year or two later.

[68] Values for years in which the number of projects where technology transfer is known but very small – China in 2004, India in 2004 and Brazil in 2010 and 2011, and all countries in 2012 – are not shown in Figure 7.

Figure 7. **Trends in technology transfer claims by host country**



Source: Based on data provided in the PDDs for 3,949 projects registered and undergoing registration as of June 2012. Percentages of technology transfer claims are based on 3,249 projects where claims could be determined.

Several factors contribute to these results. First, as more projects of a given type are implemented in a country, the rate of new technology transfer declines, since local technology access has been created through previous projects. Second, the transfer of technologies used by CDM projects appears to have been happening through other channels as well, for example via licensing, foreign direct investment, research and development networks, mergers, acquisitions and the recruitment of foreign experts.[69] Third, the rate of technological change for technologies used by CDM projects varies over time. The costs of wind projects, for example, have declined over the life of the CDM.[70] If the difference between domestically available technology and more advanced imported technology is small, a CDM project is more likely to choose the local supplier. Finally, changes in the mix of registered projects may affect the rate of technology transfer since each project type has a different frequency of technology transfer.

Over time, the need for technology transfer falls as local sources of knowledge and equipment become more available and expertise in the technologies grows. This is supported by the statistical analysis reported in Section 3.8 and is evident as the steeper decline in transfer rates for Brazil, China and India relative to “other” countries. Since there have been hundreds of CDM projects in these three countries, the rate of technology adoption is expected to be faster than for other countries that have fewer CDM projects. This reflects the contribution made by the CDM to a host country and the increasing maturity in countries’ use of the CDM to reduce the need for the further inflow of technology. Nevertheless, the vast majority of host countries currently need, and obtain, technology transfer for almost all of their CDM projects.

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[69] Haščič and Johnstone, 2011; Lema and Lema, 2010.

[70] Rahman et al., 2009; Rahman et al., 2012; Lantz et al., 2012.

## 3.6. COMPARISON OF CLAIMS IN PROJECT DESIGN DOCUMENTS AND SURVEY RESPONSES

PDDs are excellent sources of information but there is no specific requirement for participants to report transfer of technology in a uniform way. This information has to be gathered from statements made in PDDs which are often implicit and not explicit. For instance, a participant may state that the project is importing equipment that is not available in the host country, but will not mention that the foreign technology supplier will train the domestic staff in its operation. As such, the statement made in the PDD will be recorded as involving a transfer of equipment only when it may have involved a transfer of knowledge as well. Table 4 makes an attempt to adress this by making a comparison of three types of technology transfer (TT) claims in the project design documents versus a survey conducted by the secretariat in 2011, without differentating between transfer equipment and knowledge.

Table 4. **Comparison of three types of technology transfer claims in the project design documents versus survey responses**

| | Survey responses | | | |
|---|---|---|---|---|
| PDD Claims | Participant specifically states NO technology transfer | Technology transfer is unknown | Participant specifically states technology transfer | Total |
| PDD specifically states NO technology transfer | 62% | 4% | 34% | **117** |
| Technology transfer is unknown | 24% | 6% | 70% | **93** |
| PDD states technology transfer | 10% | 3% | 87% | **198** |
| **Total** | **114** | **16** | **278** | **408** |

Source: Based on the data provided in PDDs and surveys for 408 projects registered and undergoing registration as of June 2012.

As expected, for the PDDs that state that the project involves a technology transfer, 87 per cent of survey respondents confirm this (see Table 4). However, of the PDDs that specifically renounce any transfer of foreign technology, only 62 per cent of survey respondents confirm this. In other words, 34 per cent of projects that claim to use domestic technology in the PDDs actually involved a foreign technology while 4 per cent of respondents were not sure. Although this figure is similar to the 57 per cent reported in UNFCCC 2011, a similar survey conducted by the secretariat in 2010 found that a claim of "no technology transfer" in a project's PDD was correct 88 per cent of the time.[71] The difference is likely due to changes in the questions posed between the 2011 and 2010 surveys.

Table 4 also shows that when a PDD makes no statement on technology transfer, the project will involve international technology transfer (70 per cent) or use domestic technology (24 per cent). The reason could be participants may not know whether a project is expected to involve transfer of technology at the time the PDD is prepared. However, this becomes clearer over time as confirmed by the low response rate for there they have not made a decision on the technology supplier (6% - technology transfer is unknown).

Responses to another survey question confirmed that CDM projects contribute to the decline in the rate of technology transfer as the number of projects of a given type in a host country increases. Respondents indicate that 58 per cent of projects that claimed no technology transfer used technologies and knowledge from other CDM projects. In other words, the technology used by their project was available domestically as it had been used by another CDM project.

In summary, transfer of both equipment and knowledge is more common than anticipated in the PDDs. PDD claims of technology transfer seem to be (87 per cent) accurate, but claims of domestic technology are not fully supported (62 per cent) by surveys. This is probably due to ambiguities in the survey questionnaire rather than inaccuracies in the PDDs. Where PDDs make no statement relating to technology transfer, 70 per cent actually involve a transfer. Of the projects that involve no technology transfer, 58 per cent use technology from other CDM projects.

## 3.7. SOURCES OF IMPORTED TECHNOLOGY

Although almost 40 per cent of CDM projects claim technology transfer, judging whether a technology is imported or domestic can be complicated (Li, 2010). The equipment manufacturer may be located in the host country or a foreign country. A domestic manufacturer may be locally-owned and use its own or jointly developed technology, be locally-owned and use foreign technology under licence, or be a subsidiary of a foreign manufacturer. Equipment from a foreign manufacturer may be imported by a host country subsidiary or by the CDM project participants. So the location of the equipment manufacturer and the technology ownership may differ. PDD claims appear to reflect a mix of manufacturer location and location of the technology owner.

Sources of the technology used by 177 CDM wind projects registered during 2009 and the first half of 2010 were compiled by Li (2010). Sixty-seven per cent of the projects used equipment manufactured in China and 15 per cent used equipment manufactured in India. Subsidiaries of foreign manufacturers supplied 23 per cent of the equipment manufactured in China and 42 per cent of the equipment manufactured in India. The share of domestic manufacture rose between 2009 and 2010 consistent with the trend in Figure 7. The distribution of technology sources is consistent with the global market shares.

Statements in the PDDs relating to the sources of imported technology indicate that they come from a relatively small set of countries. This is to be expected given that most innovation for climate mitigation technologies occurs in developed countries.[72] As shown in Figure 8, the top five technology suppliers for CDM projects are Germany, the USA, Denmark, Japan and China.[73] To date about 85 per cent of the CDM projects that involve technology transfer get their technology from developed countries. Although not shown, the relative distribution of supplier countries is likely to have changed over time.

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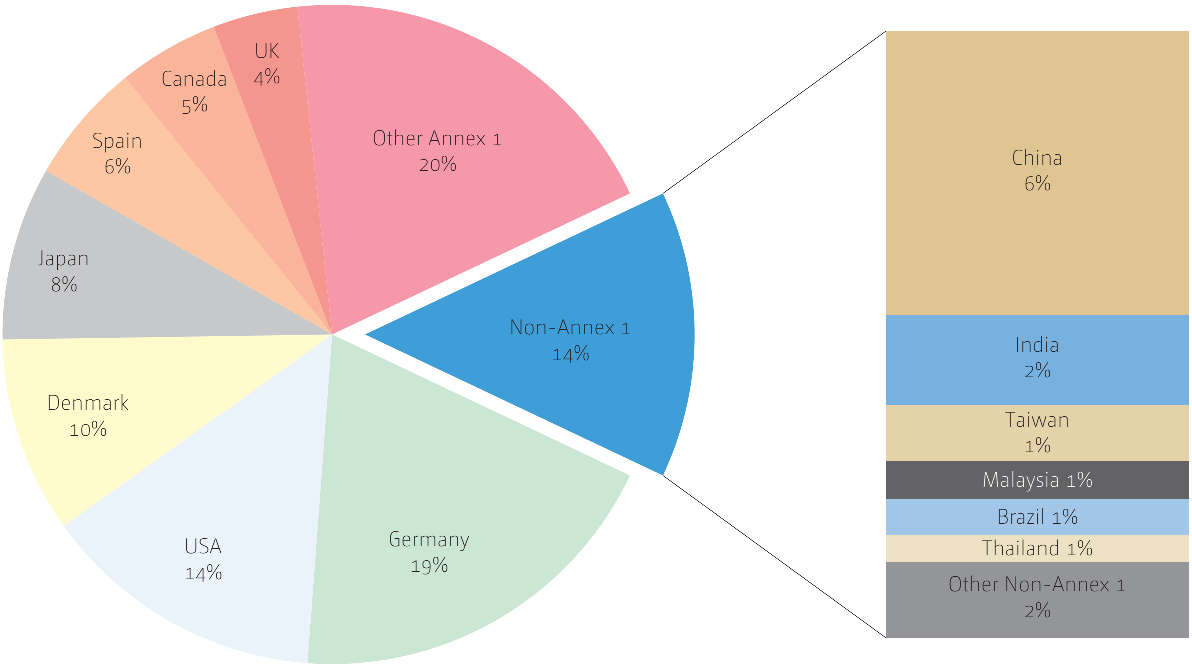
[71] UNFCCC, 2010, Table A-8, p. 37.

[72] Sixty percent of patents for 13 climate mitigation technologies originate in the U.S., Japan, or Germany Johnstone et al. 2010; Dechezleprêtre et al. 2011; Popp 2011.

[73] The source of the technology is unknown for about 20 per cent of the projects that involve technology transfer, at least partly, because the technology has not yet been sourced. If more than one country supplied technology to a project, each country is credited with a fraction of a project.

Figure 8. **Leading sources of technology supplier countries (as percentage of projects)**



Source: Based on data provided in the PDDs for 3,949 projects registered and undergoing registration as of June 2012.

Most project types use technology from several countries as shown in Table A-3. Germany supplies technology for the largest number of projects, and is the main supplier for five project types – Energy efficiency households, $N_2O$ destruction, wind and, level with Japan, cement and HFCs. The USA is the largest technology supplier for six project types (see Table A-3). China is the main supplier of technology for hydro projects and Vietnam is the largest technology supplier for energy efficiency supply side projects.

A large market share for a few technology suppliers might indicate that the technology is controlled by a few sources, an oligopoly, which could restrict the distribution of the technology and/or keep the price relatively high. The number of supplier countries and the market shares of the largest supplier country and four largest supplier countries are presented in Table A-3. Of the 11 project types with at least 25 projects that claim technology transfer, only energy efficiency own generation has a largest foreign supplier country whose share exceeds 50 per cent. The combined share of the four largest supplier countries across these 11 project types ranges from 29 to 97 per cent. The number of foreign supplier countries is 10 or more except for energy efficiency own generation, coal bed/mine methane and solar where it is seven, nine and nine respectively.

The market shares of technology suppliers are lower than indicated by these figures. Since the firm(s) supplying the technology often is not specified in the PDD, the figures are calculated on the basis of supplier countries. Some countries have a few firms that supply a given technology, so the firm shares would be lower. The project types with sufficient data suggest that project developers have a choice among a number of domestic and/or foreign suppliers with no dominant supplier able to restrict the distribution of the technology and/or keep the price high.

## 3.8. STATISTICAL ANALYSIS OF TECHNOLOGY TRANSFER

Statistical analyses seek to identify the characteristics of CDM projects and host countries that influence the rate of technology transfer. Studies have conducted such analyses by estimating a single equation[74] or two equations.[75] With a single equation, technology transfer for a CDM project is related to the project type, project characteristics (size, small-scale, etc.) and various host country characteristics (population, per capita GDP, etc.).[76]

With two equations, the first equation relates technology transfer to project type, project characteristics, year the project was registered and the host country, but not the host country characteristics. This equation is then used to predict the probability of technology transfer for each combination of project type, host country and year based on the characteristics of the CDM projects registered in the host country that year.[77] The second equation relates the predicted probabilities to host country characteristics to identify those that influence the rate of technology transfer.[78]

The equations estimated for this report are presented in Table A-4. The statistical performance for the single equation is satisfactory, with a pseudo $r^2$ of 0.57 and correct prediction of over 88 per cent of the observations.[79] The results indicate that:

- Larger projects are more likely to involve technology transfer;
- Small-scale projects are less likely to involve technology transfer; and
- Technology transfer falls as the number of projects of the same type in a host country increases.

The year variables indicate that the rate of technology transfer has changed significantly over the life of the CDM (2004 – 2012).[80] Technology transfer was more common during the early years of the CDM and has become less frequent since 2007. This is clearer from the two equation approach where all of the year variables are retained. Of the 12 project types included in the equation, biomass energy and cement, projects are less likely to involve technology transfer while energy efficiency supply side and wind projects are more likely to involve technology transfer.[81]

The two equation approach allows the analysis of more project start years, project types and inclusion of host country dummy variables in the first equation.[82] Again, the statistical results are satisfactory with a pseudo $r^2$ of 0.49 and correct prediction of over 85 per cent of the observations for the first equation and an adjusted $r^2$ of 0.43 for the second equation.[83] Equation 1 confirms the results reported above for the project characteristic and project start year variables.

Equation 1 also shows that the host country has a significant influence on the rate of technology transfer; 16 of the 22 host country variables are statistically significant. With a strictly random distribution about 5 per cent of the host countries, only 1 or 2, would be statistically significant. Consistent with Figure 7, all host countries except India, have a positive coefficient indicating a higher rate of technology transfer than China, the reference country.

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[74] Haites et al. 2006; UNFCCC 2007; Dechezleprêtre et al., 2008; UNFCCC 2008; Doranova et al., 2010; and Schmid, 2012. Zheng and Zhang (2011) analyse technology transfer for CDM projects in different provinces of China.

[75] UNFCCC 2010; and Haites et al. 2012.

[76] A project either involves technology transfer (TT=1) or does not (TT=0). With a dependent variable that can only take the values 0 or 1, the appropriate form of regression is a binomial logit model.

[77] If a single project of a given type is registered during a year in a specific country, the predicted probability is approximately equal to the claimed technology transfer (TT=1 or TT=0) for that project. With multiple projects, the probability reflects their average characteristics and has a value between 0 and 1. For example, wind projects in India registered in 2005 are predicted to have a 0.3681 probability of technology transfer.

[78] The regression for the first equation is a binomial logit model. Since the predicted probabilities can have any value between 0 and 1 inclusive, the second equation is estimated using ordinary least squares.

[79] The pseudo $r^2$ and percentage of observations correctly classified are indicators of the explanatory power of the equation.

[80] During the first few years, projects with a start date from 2000 onward could be registered. The year variables except for the period 2003 through 2009 are dropped for statistical reasons.

[81] The likelihood of technology transfer is relative to that for hydro (the reference project type) which has a relatively low rate of technology transfer.

[82] A dummy variable takes the value of 1 for that characteristic and zero otherwise. The India variable has a value of 1 for all Indian projects and zero for all other projects. The coefficient for the variable indicates whether the characteristic is statistically significant.

[83] Since the predicted probabilities, the dependent variable for the second equation, can take any value between 0 and 1, it is not possible to calculate the percentage of observations classified correctly.

The coefficients for 14 of 19 project types are statistically significant, indicating that the rate of technology transfer differs among project types. These results are basically consistent with but more comprehensive and robust than those of the single equation approach. Only the coefficients for afforestation/reforestation and fugitive are negative and statistically significant indicating a low rate of technology transfer relative to hydro, the reference project type. The results also confirm the trend shown in Figure 7, relatively high rates of technology transfer during the early years of the CDM and lower rates since 2007.

The statistical analysis suggests that GDP per capita, foreign direct investment (FDI), renewable share of electricity generation, and knowledge stock[84] are host country characteristics that have a significant impact on the rate of technology transfer via the CDM. The host country's knowledge stock specific to the project type reduces the rate of technology transfer because more is already available. A larger emission reduction potential for the project type reduces the rate of technology transfer perhaps because such projects are already being implemented.[85] A higher marginal emission reduction cost for the project type indicates that such projects have been relatively unattractive so CDM projects increase the rate of technology transfer.

Different time lags were tested for the impact of host country characteristics on the rate of technology transfer via CDM projects. All of the characteristics have a lag of one to three years, but the results for a lag that is a year shorter or longer are often similar. These results suggest that the rate of technology transfer responds relatively quickly to changes in host country characteristics. The significant changes in the rate of technology transfer over the life of the CDM confirm the responsiveness of technology transfer to change.

## 3.9. OTHER STUDIES ON TECHNOLOGY TRANSFER AND THE CLEAN DEVELOPMENT MECHANISM

Numerous papers have analysed technology transfer by CDM projects for registered projects or projects in the pipeline using information from PDDs.[86] [87] All of these papers find that a substantial share of the CDM projects claim technology transfer. Differences in the percentage of projects that claim technology transfer are largely due to the treatment of those whose PDD includes no statements relating to technology transfer and to the decline in the rate of technology transfer via CDM projects over time.

All of the studies agree that the frequency of technology transfer varies with the project characteristics, including project type and size, with larger projects being more likely to involve technology transfer. Projects that involve a subsidiary of a foreign partner are more likely to involve technology transfer or, conversely, unilateral projects are less likely to involve technology transfer. Technology transfer falls as the number of projects of the same type in a host country increases.

The studies have analysed a variety of host country characteristics for their impact on the rate of technology transfer.[88] There is strong evidence that the host country has a significant impact on the rate of technology transfer, but less agreement on which characteristics are important. Technology transfer for CDM projects tends to be less common for larger, wealthier host countries as measured by population, GDP and GDP per capita.[89]

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[84] The knowledge stock is the discounted stock of patents issued – patent stock of the previous year multiplied by 0.9 plus patents issued during the year. The knowledge stock for a specific project type, such as wind, is calculated in the same way using only patents related to wind technology.

[85] The emission reduction potential and marginal emission reduction cost are from marginal abatement cost curves for host countries. They estimate the potential for, and marginal cost of, greenhouse gas emission reductions by various measures relative to conventional technology.

[86] Haites et al., 2006; de Coninck et al., 2007; UNFCCC 2007; Dechezleprêtre et al., 2008; UNFCCC 2008; Seres et al., 2009; Doranova et al., 2010; UNFCCC 2010; Das, 2011; Zheng and Zhang, 2011; Schmid, 2012; TERI, 2012; and Haites et al., 2012.

[87] A statistical test indicates that registered projects and projects in the pipeline that have not yet been registered are similar in terms of technology transfer and can be grouped together for analysis. (UNFCCC 2010, Annex B).

[88] The statistical analyses do not distinguish the nature of the technology transfer claimed by the project. Schmid (2012) also estimates separate equations for projects that claim knowledge only, equipment only, and both knowledge and equipment and finds no significant differences in the results.

[89] In some analyses, the coefficients for these variables are not statistically significant.

FDI is another channel for technology transfer. Host countries that are more attractive for FDI have lower rates of technology transfer for CDM projects. Trade, likewise, is another channel for technology transfer. Several measures[90] of a host country's openness to trade have been used with mixed results – some suggest that openness to trade increases technology transfer via CDM projects while others find that it reduces the rate of technology transfer for CDM projects.[91]

Several studies include the host country's technological capacity as measured by research and development spending as a percentage of GDP, tertiary school enrolment, patent applications, and the ArCo index in the analysis.[92] In almost every case the coefficient is not statistically significant.[93] Greater technological capacity relevant to the project type reduces the frequency of technology transfer for CDM projects.[94] Thus technological capacity related to the project type, rather than general technological capacity, may be more relevant.

Few of the analyses explicitly include time despite the significant decline in the rate of technology transfer over the life of the CDM shown in Figure 7. Where time is included, the results confirm the pattern of declining frequency of technology transfer over time in Figure 7.[95] The results also suggest that the rate of technology transfer responds fairly quickly – one to three years – to changes in host country characteristics.

Such statistical analyses are complemented by studies of technology transfer for CDM projects in specific countries. Country studies focus on policies, institutional structures and other factors that can affect technology transfer for CDM projects. China, host of the largest number of CDM projects, is the subject of the most country studies.[96] India and Chile are each covered by two studies.[97] Brazil, Israel, Kenya, Malaysia, Mexico and Thailand are each addressed by a single study.[98] It is difficult to draw general conclusions from these country studies because, as the statistical analyses show, each country is unique.

## 3.10. INTERNATIONAL TRANSFER OF WIND TECHNOLOGY AND THE CDM

The statistical analyses presented above are all based on statements contained in the PDDs of CDM projects. Haščič and Johnstone (2011) assess the contribution of the CDM to the international transfer of wind technology to developing countries from an aggregate perspective using patent data. A patent for a technology granted by one country subsequently registered in another country (a duplicate patent) is used as a measure of technology transfer to that country. This covers all mechanisms for transfer of technology including licensing, foreign direct investment, and trade as well as the CDM and other channels.

Haščič and Johnstone (2011) analyse data on patents for wind technology issued in a developed country with a duplicate patent registered in a developing country between 1988 and 2007 inclusive. To test whether CDM projects contribute to the rate of technology transfer to developing countries, they include the CERs issued for wind projects. The data cover only a few years of CDM activity. Nevertheless, they find that the CDM has had a statistically significant influence on the extent of transfer between developed and developing countries, but that this effect is relatively small compared with other factors.

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[90] Measures include imports as a percentage of GDP, exports as a percentage of GDP, imports plus exports as a percentage of GDP, average tariff rate, and most favoured tariff rate on environmental goods.

[91] For example, Dechezleprêtre et al., 2008 and Doranova et al., 2010,) find increased technology transfer for CDM projects (positive coefficients) while Haites et al., 2012 and Schmid, 2012 find that more openness to trade reduces technology transfer for CDM projects (negative coefficients).

[92] Archibugi and Coco, 2004.

[93] Haites et al, 2012 and Schmid, 2012. Dechezleprêtre et al., 2008 find that the sign and statistical significance differ by sector.

[94] Haites et al., 2012.

[95] Haites et al., 2012.

[96] Dechezleprêtre et al., 2009; ENTTRANS consortium, 2008; Lema and Lema, 2010; Marconi and Sanna-Randaccio, 2011; Shen, 2011; and Wang, 2010.

[97] Dechezleprêtre et al., 2009 and Lema and Lema, 2010 for India and ENTTRANS consortium 2008 and Pueyo Velsaco 2012 for Chile.

[98] Dechezleprêtre et al., 2009 for Brazil and Mexico; ENTTRANS consortium 2008 for Israel, Kenya and Thailand; and Hansen 2008 for Malaysia.

For this study the Haščič and Johnstone analysis was replicated and expanded using updated data (1988 through 2009) on duplicate patents.[99] These data cover international transfer of wind technology between 152 source and 101 recipient countries and regions, although some dropped out of the statistical analysis.[100] The statistical analysis covered all international transfers, not only transfers from developed to developing countries. Consistent with the results from analyses of PDD claims, the recipient country has a significant impact on the rate of technology transfer.[101] The rate of technology transfer for wind technology has increased over time.[102] Confirming the Haščič and Johnstone result, larger emission reductions for CDM wind projects increase the rate of technology transfer to the host country.

## 3.11. SUMMARY

There is no doubt that the CDM facilitates technology transfer to host countries. Approximately a third of all projects claim to import equipment and/or knowledge. This understates the extent of technology transfer because it is now known that more than half of the projects that do not claim technology transfer use technologies from other CDM projects or imported knowledge and/or equipment.

This study, and others, show that the frequency of technology transfer declines over time as local expertise related to the relevant technologies grows. CDM project activities help develop this expertise; the frequency of technology transfer declines as the number of projects of a given type in a host country increases. The frequency of technology transfer via CDM projects has declined over time in China, India and Brazil – the countries that host the largest numbers of projects – but remains high in almost all other host countries.

The frequency of technology transfer differs significantly by project type and by host country. Not surprisingly, the rate of technology transfer is lowest for hydro and cement projects, which use mature technologies already widely available in developing countries. Many countries have requirements related to the technology used by CDM projects, separately or as part of their sustainable development criteria, which explains why the host country has an impact on the frequency of technology transfer.

A comparison of technology transfer in projects across different countries shows that CDM host country characteristics, such as population, GDP per capita, foreign direct investment, renewable share of electricity generation and knowledge stock significantly impact the rate of technology transfer via the CDM. Furthermore, a change to these host country characteristics has an almost immediate effect (after just one to two years) on the rate of technology transfer. Efforts to identify the specific characteristics that influence the rate of technology transfer have made some progress, but further research is needed.

Innovation on climate mitigation technologies occurs primarily in developed countries, with the top five technology suppliers for CDM projects being Germany, the USA, Denmark, Japan and China. Within these countries there tend to be many technology suppliers indicating that project developers have a choice among a number of domestic and/or foreign suppliers with no dominant supplier able to restrict the distribution of the technology and/or keep the price high.

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[99] For most recipient countries the number of duplicate wind patents registered during a year is zero. Special efforts have been made to distinguish zero values from missing values.

[100] Many (approximately 40) developing countries are members of regional patent organizations for which a single registration covers all member countries.

[101] 60 of 63 country dummy variables are statistically significant. Almost all recipient countries have a lower rate of transfer for wind technology than China.

[102] The coefficients for the year dummy variables, with a few exceptions, rise from one year to the next. Since 1994, with the exception of 1996, all of the year variables are statistically significant.

# IV. CDM PROJECT FINANCE AND COSTS

The CDM was conceived as a mechanism to facilitate an efficient global response to climate change. The premise underlying the CDM is that greenhouse gas emissions could be reduced at lower cost in non-Annex I countries than in Annex I countries. Non-Annex I countries hosting emission reduction projects would reap sustainable development and other benefits and profit from the sale of the emission reduction credits. Annex I countries could lower the cost of meeting their emissions reduction commitments by buying credits from CDM projects.

Some experts assumed that most CDM projects would involve Annex I investors who would provide capital in return for credits. The rules also allow unilateral projects – projects implemented by host country investors. While some CDM projects have investors from Annex I (and non-Annex I) countries, an emissions reduction purchase agreement (ERPA) is the most common arrangement. Under an ERPA a project developer commits to implement an emission reduction project and the Annex I entities commit to buy credits generated by the project at specified prices.

This section explores several of these issues. First it examines the estimated investment in CDM projects disaggregated by project type, host country, year and sources of foreign investment. Second, it compares renewable energy CDM projects with similar projects in Annex I countries in terms of size, capital intensity, average investment and trends in the share of foreign investment. The estimated mitigation costs for CDM projects are the third topic addressed. The fourth item covered is the revenue earned from the sale of CERs by year and host country. Finally, the compliance cost savings for Annex I entities and governments due to the use of CERs are estimated.

## 4.1. INVESTMENT TRIGGERED BY CDM PROJECTS

### 4.1.1. Investment by project type

Approximately 60 per cent of CDM projects report their estimated capital investment in their PDD. In order to calculate the capital investment for the remaining 40 per cent, the average capital investment by project type, and sub-type, was divided by the expected annual emission reductions of the project. This yielded a metric that was useful for two purposes. First, it allowed the comparison of capital input. The capital investment per tonne of $CO_2$ equivalent per annum reduced differs significantly by project type and subtype as shown in Figure 9, ranging from USD 9/t $CO_2$ e for $N_2O$ projects to USD 4,004/t $CO_2$ e for solar projects. [103] Secondly, applying these averages to the projects that do not provide the estimated investment in the PDD yields an estimate of the total investment in CDM projects (see Annex B).

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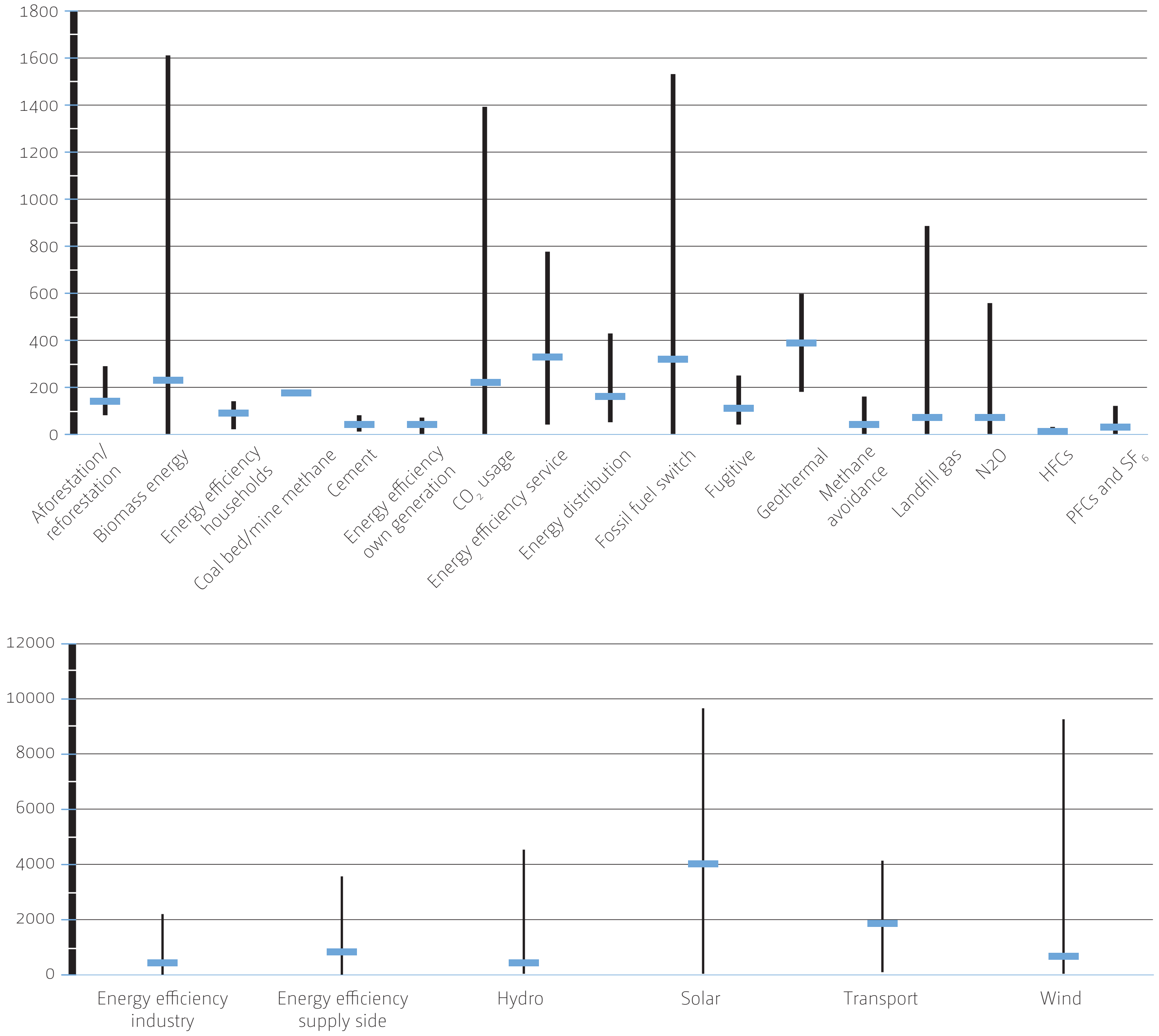
[103] This metric is expressed as USD/t $CO_2$ e but should not be confused with project mitigation or abatement cost which is expressed similarly, but is calculated differently.

Figure 9. **Capital investment (USD) per tonne of $CO_2$ equivalent by project type (mean, minimum, maximum)**



Source: Calculated using the estimated capital investment and expected annual tonnes of $CO_2$e emissions reduced as stated in PDDs for 2,860 projects registered and undergoing registration as of June 2012. The average capital investment per tonne of annual $CO_2$e reduced is the sum of the estimated capital investment for the projects of a given type divided by the sum of the expected annual emission reductions for those same projects. The minimum and maximum are determined from values calculated for individual projects.

The total investment in CDM projects registered and undergoing registration as of June 2012 amounts to USD 215.4 billion. Of that total, the investment in projects that are known to be operating [104] is USD 92.2 billion, USD 87.6 billion for registered projects where it is not certain if they have started operating and USD 35.5 billion for projects undergoing registration. Total investment by project type is shown in Table A-5. The total is dominated by wind and hydro due to the large number of projects and the capital-intensive nature of these technologies.

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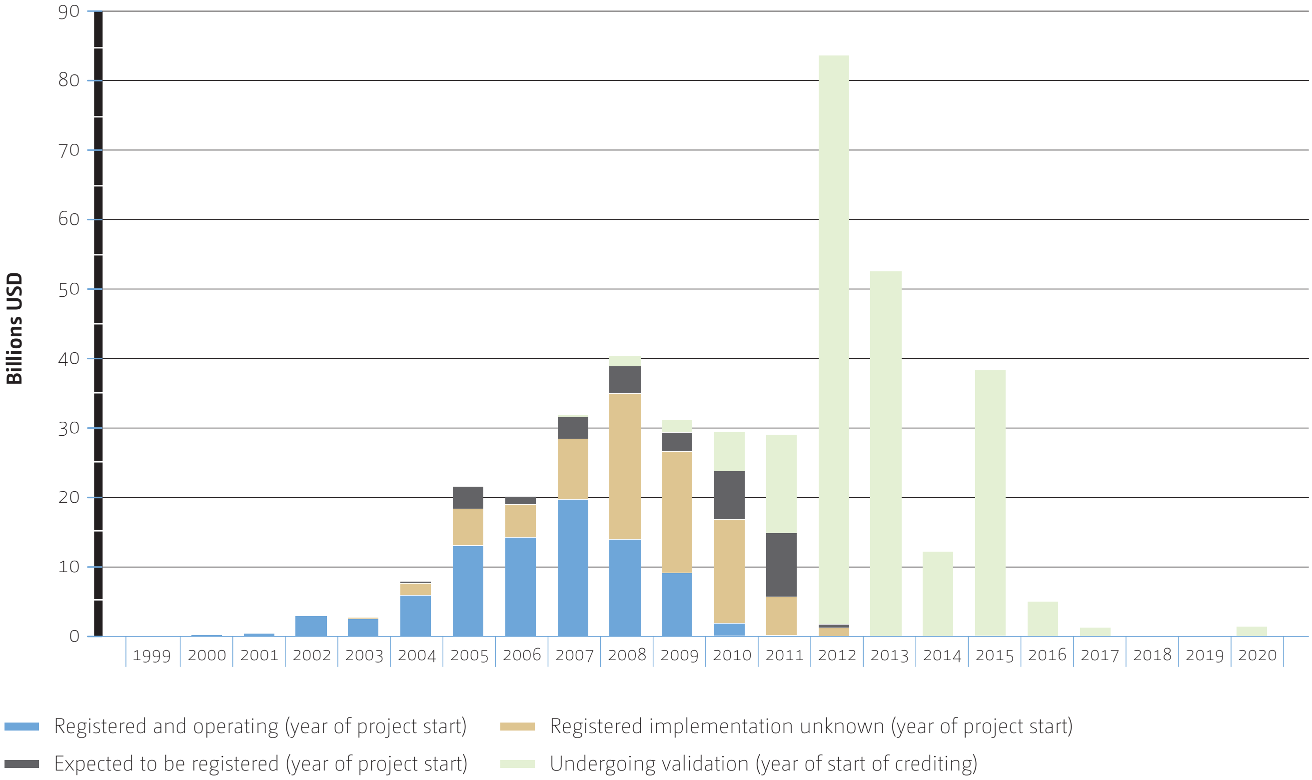
[104] A project is considered operational if it has submitted a monitoring report to the UNFCCC secretariat, indicating that emission reductions have started to be monitored. This approach is very conservative since it excludes projects that are operating, but have not submitted a monitoring report yet.

### 4.1.2 Investment by year

The annual investment in CDM projects is shown in Figure 10.[105] Annual investment appears to have peaked in 2008 at between USD 13.9 billion (operating projects) and USD 40.4 billion (all projects). The apparent decline in investment in operating or registered projects from 2009 onward is due mainly to the lag between the start date[106] and the date of submission of the monitoring report (reliable evidence that the project is operating). On average GHG monitoring starts 3,8 years after the project starts. Therefore, it is likely that more projects have been implemented and more investment has taken place than is shown in Figure 10. In any event, the large number of projects undergoing validation may lead to a new, much higher, peak in annual capital investment in 2012.

The annual investment figures presented here differ from those reported in 2011 due largely to the year of the investment used.[107] The 2011 study covered a smaller number of registered projects and reported the investment as occurring in the year the project was registered. Here the investment is assumed to occur during the year the projects started, as contained in the PDD, for registered projects and those undergoing registration and the year in which the crediting period is expected to start, for projects at validation.

Figure 10. **Investment in CDM projects by year as of June 2012**



Source: Based on the reported or estimated capital investment for 4,832 projects registered and undergoing registration and 4,472 projects undergoing validation as of June 2012.

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[105] Project start year was used for projects registered or undergoing registration and the year of first CER issuance was used for projects undergoing validation.

[106] The date the project participants stated the project would be implemented in the PDD.

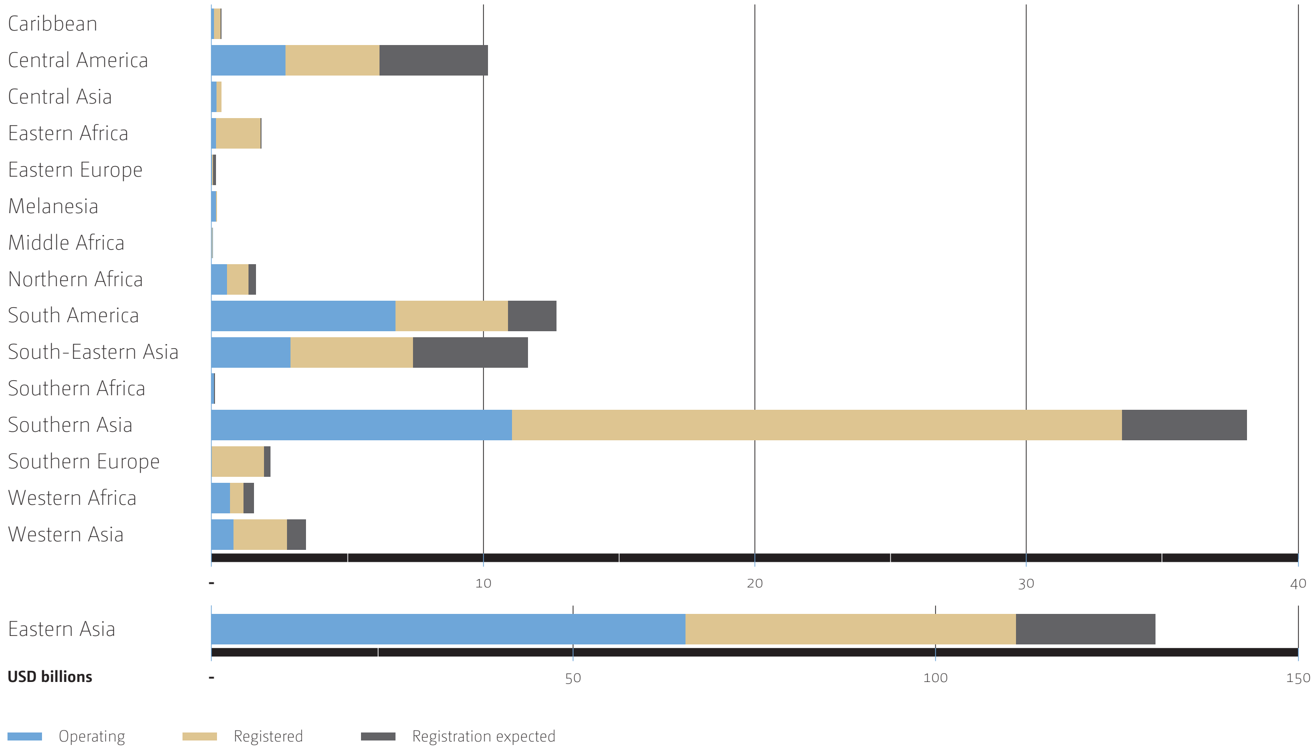
[107] UNFCCC, 2011, table IV-9, p. 29.

Estimated investment in CDM projects by year is also reported by UNEP Risø. The investment for registered projects reported in the June 2012 edition of the CDM Pipeline, which covered 4,170 projects, totals USD 195.7 billion, which is higher than estimates provided here (USD 179.8 billion for 4,224 registered projects).[108] The difference, of approximately USD 16 billion from 54 fewer projects, is due to differences in local currency conversion to United States dollars and assumptions made in extrapolating missing values.

### 4.1.3. Geographic distribution of investment

The estimated total investment in projects registered and undergoing registration by host country region is shown in Figure 11. China and India which make up the bulk of projects in Eastern Asia and Southern Asia respectively account for 65 per cent of the total investment with 45 per cent of the projects (see Table A-6). Projects in Eastern Asia have relatively large capital investment due to the capital-intensive nature of the projects undertaken (renewables) and their large average size. In contrast, the capital intensity of almost every other region is equal to or below the overall average. The estimated capital investment in registered and registering CDM projects by host country is presented in Table A-6.

Figure 11. **Investment in CDM projects by United Nations sub-region as of June 2012**



Source: Calculated using the reported or estimated capital investment for 4,832 projects registered and undergoing registration as of June 2012.

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[108] USD 92.2 billion for 2,349 operational projects plus USD 87.6 billion for 1,875 other registered projects.

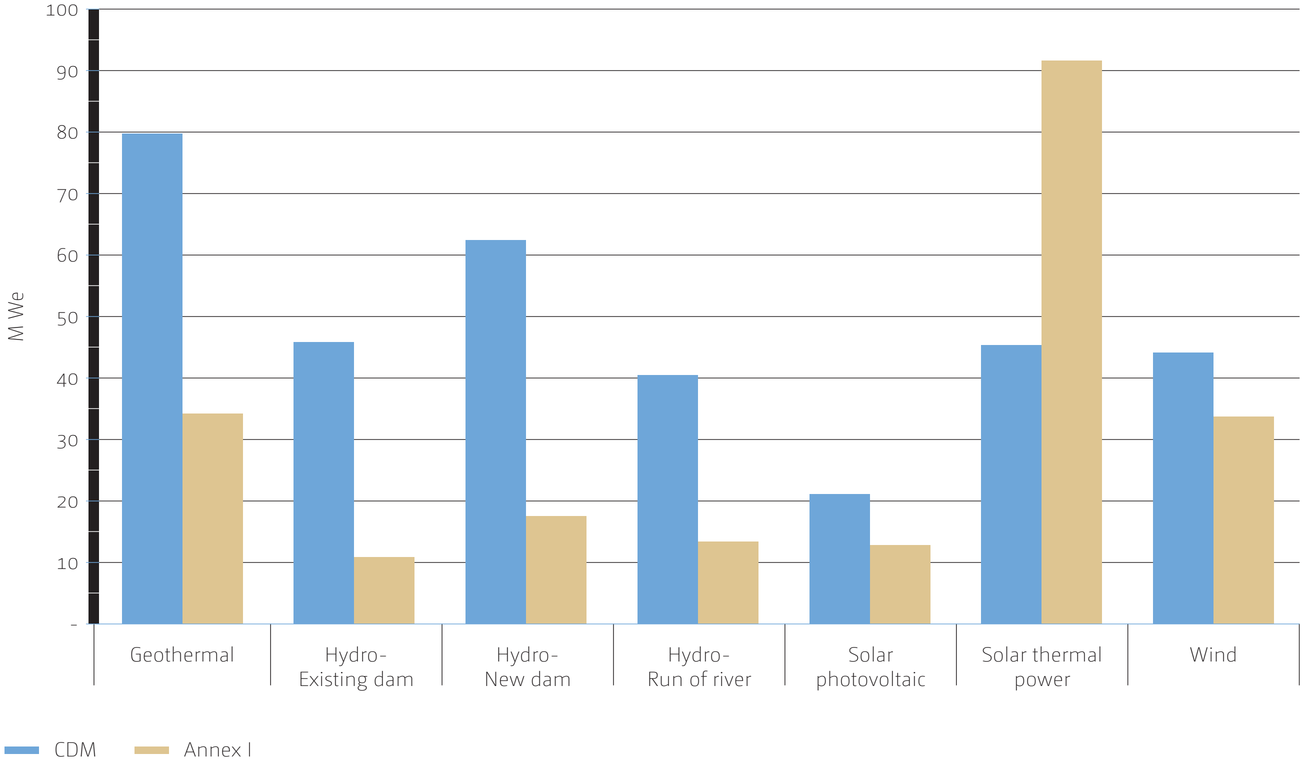
## 4.2. COMPARISON OF CDM PROJECTS WITH SIMILAR PROJECTS IN ANNEX I COUNTRIES

Data on capital investment and financing for projects primarily in Annex I countries (non-CDM projects) is recorded by Bloomberg New Energy Finance (BNEF). These data include renewable energy projects in Annex I countries and CDM projects. There are very few non-CDM projects in non-Annex I countries and most of them are from prior to 2000 (see Annex B)[109].

### 4.2.1. Average power generation capacity

Figure 12 compares the average electrical power generation capacity (MWe) per project by project type for CDM and non-CDM projects in Annex I countries. With the exception of solar thermal projects, CDM projects are larger than similar non-CDM projects, often three or four times the size. More rapid growth in the demand for electricity in non-Annex I countries creates more opportunity for larger renewable projects in those countries. The hydropower potential in developing countries includes large sites as developing countries have more undeveloped large rivers than non-Annex I countries. Similarly, the average wind power project in China is generally much larger than is practically possible for example in Europe due to spatial planning regulations.[110]

Figure 12. **Average power generation capacity (MWe) per project by project type for CDM and non-CDM projects**



Source: Based on 4,808 CDM and 2,952 Annex I renewable energy projects.

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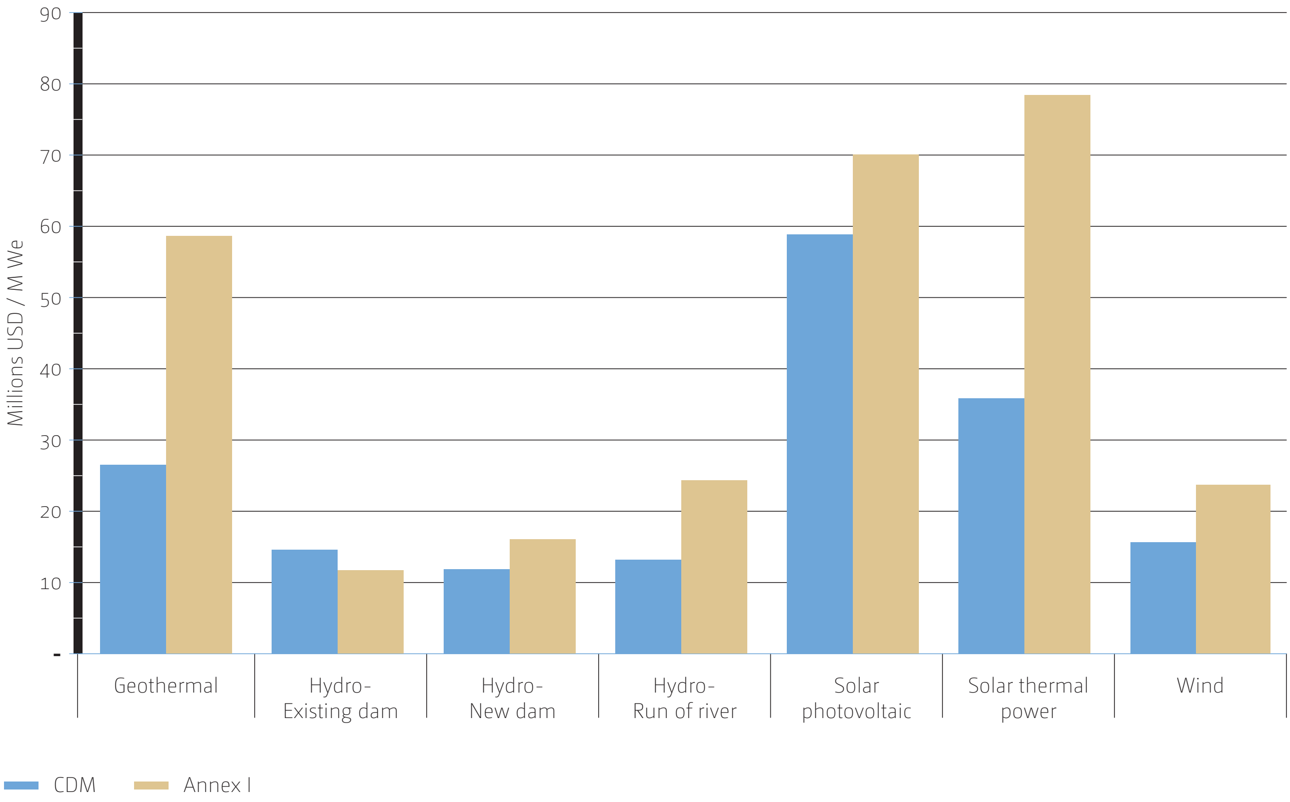
[109] The following project types are recorded by BNEF: afforestation/reforestation, cement, $CO_2$ usage, coal bed/mine methane, energy efficiency households, energy efficiency industry, energy efficiency own generation, energy efficiency service, energy efficiency supply side, energy distribution, fossil fuel switch, fugitive, HFCs, $N_2O$, PFCs and $SF_6$ and transport.

[110] Most of the CDM wind projects are located in China.

### 4.2.2. Average capital intensity

Figure 13 compares the capital intensity of CDM and non-CDM projects by project type. Capital intensity is the average capital investment per unit of capacity (USD/MWe). With the exception of existing dam hydropower projects, CDM projects are 15 per cent (solar photovoltaic) to 50 per cent (geothermal and solar thermal power) less capital intensive than similar Annex I projects. This may be due to economies of scale for the larger CDM projects; for some technologies larger projects have a lower capital investment per unit of capacity. Projects in developing countries also may benefit from lower labour costs.

Figure 13. **Capital intensity (investment as USD/MWe) by project type for CDM and non-CDM projects**



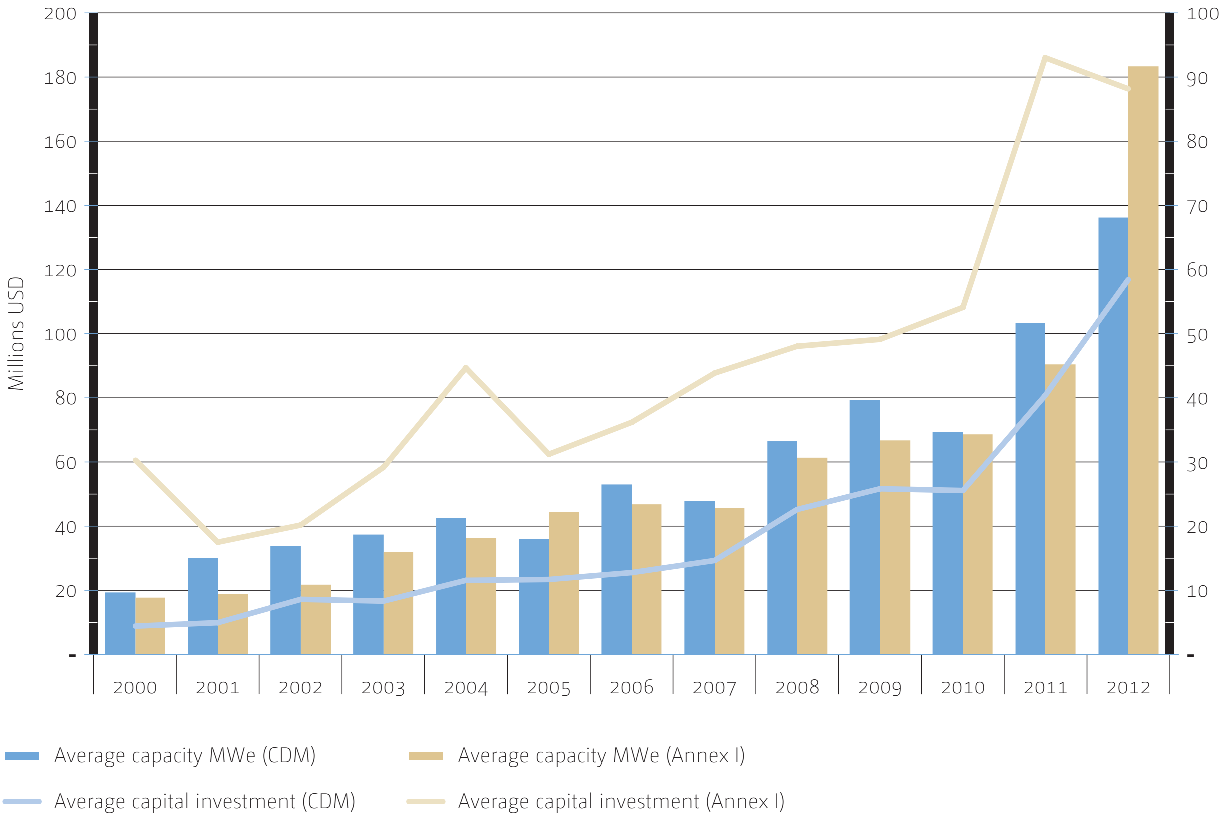
Source: Based on 4,808 CDM and 2,952 Annex I renewable energy projects.

### 4.2.3. Average capital investment

The average capital cost investment per project is lower for CDM projects.[111] Even though the average capacity of CDM projects is generally larger, their capital intensity is lower resulting in a significantly lower average capital investment for CDM projects as compared to similar Annex I projects.

The average capital investment for CDM projects remains lower throughout 2000 to 2012 but the average capital investment of both CDM and Annex I projects increased rapidly during this period (see Figure 14) – from USD 10 million to almost USD 120 million for CDM projects and from USD 35 million to about USD 180 million for Annex I projects. This is due to a sharp increase in the overall size of renewable energy projects between 2000 and 2012.

Figure 14. **Average capital investment per project and capacity over time for CDM and Annex I renewable energy projects**



Source: Based on 4,808 CDM and 2,952 Annex I renewable energy projects

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[111] The average capital investment for a given project type and year is equal to the average capacity for that project type and year multiplied by the capital intensity for the project type and year – (MWe/project)*(USD/MWe) = USD/project = average capital investment.

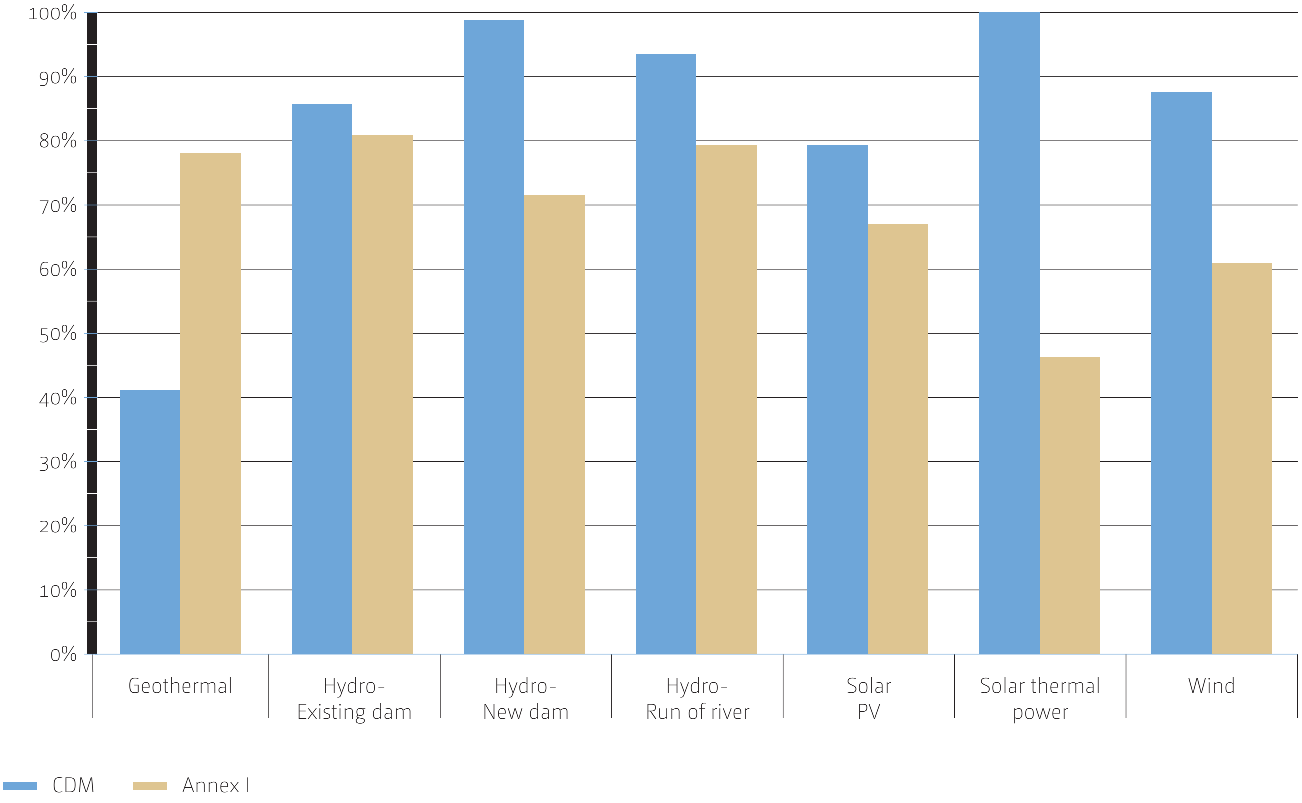
### 4.2.4. Sources of finance by project type

Information on project location and country origin of finance is used to determine whether a project is domestically or foreign financed[112]. A project is domestically financed if the only source of project finance is the host country. All other projects involve some foreign finance, but these projects usually have some domestic finance as well.

The share of solely domestically financed projects by project type is shown in Figure 15. Overall about 90 per cent of the CDM projects and 65 per cent of the Annex I projects are domestically financed[113]. With the exception of geothermal projects, 80 per cent to 100 per cent of CDM projects are domestically financed. For Annex I projects the share of domestically financed projects is lower and more variable, ranging from 45 per cent for solar thermal power to about 80 per cent for geothermal, existing dam hydropower, and run-of-river hydropower.

The remainder of the projects – about 10 per cent of the CDM projects and 35 per cent of the Annex I projects – involve some foreign finance. Almost all of those projects also have some domestic finance, so these percentages overstate the share of total investment from foreign sources. The same calculations can be performed using the capital investment rather than the number of projects. Foreign participation is higher for larger projects, so the share of total investment with some foreign investment is higher – about 20 per cent for the CDM projects and 55 per cent for the Annex I projects over the life of the CDM (see Figure 16).[114]

Figure 15. **Share of domestically financed renewable energy projects by project type**



Source: Based on 4,808 CDM and 6,445 Annex I renewable energy projects with known investor origin

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[112] Bloomberg New Energy Finance (BNEF) tracks the sources of project financing.

[113] Lütken, 2008 found that 90% of CDM projects are unilaterally financed.

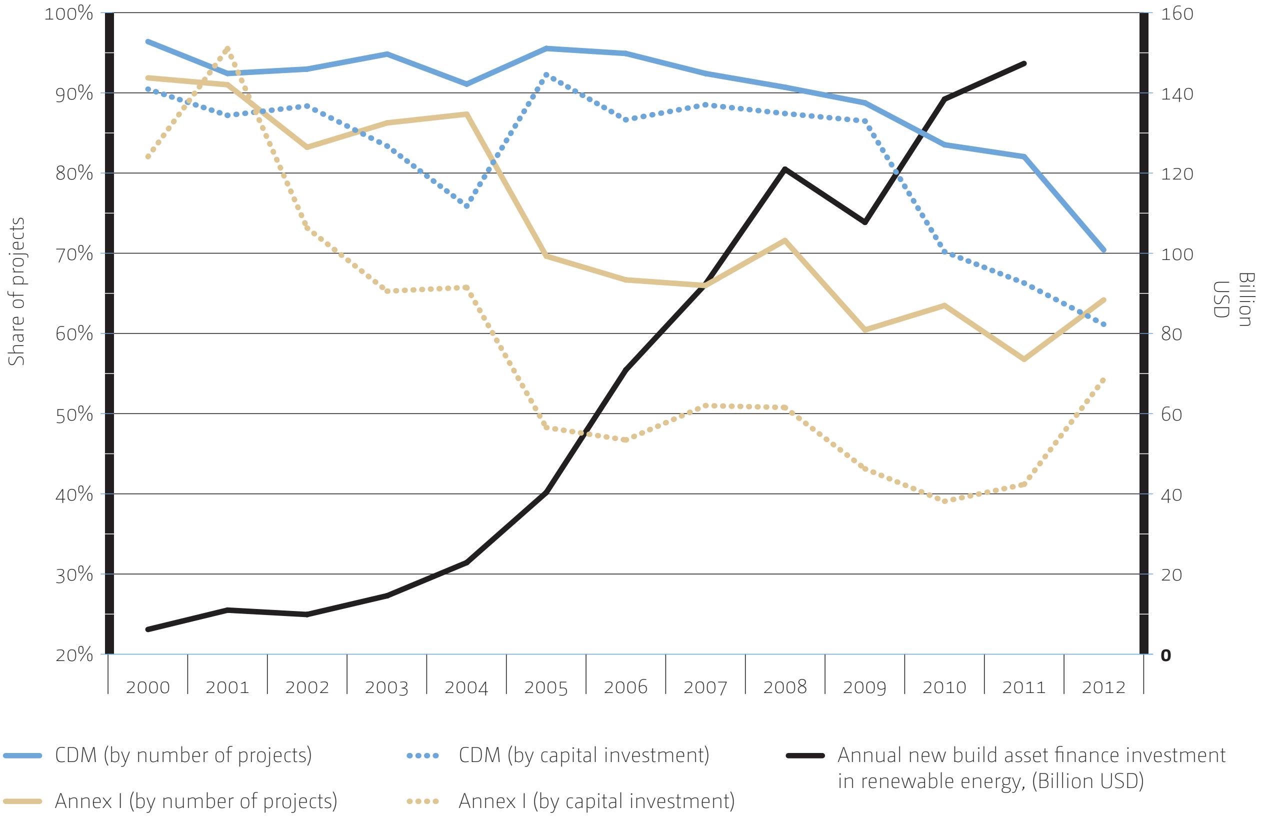
[114] 20% and 55% are the averages for the dotted lines over the period for CDM and Annex I projects respectively.

### 4.2.5. Trends in domestic and foreign finance

The trend in the share of domestically financed projects is shown in Figure 16. Over time the share of domestically financed projects has declined meaning that foreign investment has become more common for both CDM and Annex I renewable energy projects. The share of domestically financed CDM renewable energy projects dropped from 95 per cent for projects that started in 2000 to about 80 per cent for 2011 projects and 70 per cent so far for 2012. For Annex I renewable energy projects, the domestically financed share dropped from 90 per cent in 2000 to just under 60 per cent in 2011.

When calculated on the basis of capital investment rather than the number of projects, the domestically financed share dropped from about 90 per cent in 2000 to 60 per cent in 2011 for CDM renewable energy projects and from about 90 per cent in 2001 to almost 40 per cent in 2011 for Annex I renewable energy projects.

Figure 16. **Trend in the share and capital investment of domestically financed renewable energy projects**



Source: Based on 4,808 CDM and 2,952 Annex I renewable energy projects

The increasing share of projects with some foreign investment is consistent with three other trends. Foreign investment is more common for projects with a larger capital investment. Thus the trend to larger projects shown in Figure 16 suggests a rising share of projects with foreign investment, which is consistent with the growth of global investment in renewable energy projects (dashed line in Figure 16). As markets grow firms expand into foreign markets, which lead to a rising share of projects with foreign investment. Typically most inward foreign direct investment is channelled into developed countries so foreign investment would be expected to be more common for Annex I renewable energy projects.

Although the dominant trend in Figure 16 is increasing foreign investment for both CDM and Annex I renewable energy projects, there is an observed [115] inverse relationship between the share of foreign investment in renewable energy CDM projects and renewable energy projects in Annex I countries. A decrease in foreign participation for renewable energy CDM projects generally coincides with an increase in foreign participation for Annex I renewable energy projects. [116] This suggests that some of the foreign investment available for renewable energy projects may shift between non-Annex I and Annex I projects, and vice versa, as conditions in the respective countries change. More work is needed to investigate this further.

### 4.2.6. Amount of foreign investment attracted by CDM projects

In Section 4.2.4, it has been shown that approximately 10 per cent of renewable energy CDM projects have some form of foreign investment. Since larger projects are expected to attract more foreign investment, the share of total capital investment with some foreign investment is almost 20 per cent. Applying these shares to the total investment of USD 215.4 billion gives a range of USD 21.5 to USD 43.0 billion for foreign investment in projects over the life of the CDM. The lower figure may not be a lower bound since other (non-renewable) project types may have less foreign investment. The higher figure is an upper bound since projects with some foreign investment also have some domestic investment.

### 4.2.7. Sources of foreign investment in CDM projects

Most of the investment in CDM renewable energy projects is domestic, but the share of foreign investment has risen over time (see Figure 13 in Section 4.2). Of 47 host countries with CDM renewable energy projects, 11 have no foreign investment. Seven host countries have some foreign investment in all their CDM renewable energy projects, but this is only one or two projects in each case – Ecuador (2), Georgia (2), Macedonia (1), Montenegro (1), Nicaragua (1), Senegal (1) and Sierra Leone (1).

The remaining 29 host countries have some foreign investment in some, but not all of their renewable energy CDM projects. The countries with the most projects with some foreign investment are the countries with the most projects. China has 88 projects with some foreign investment (6 per cent of its total), 43 of which involve investment from Hong Kong. India has 40 projects with some foreign investment (5 per cent of its total), 24 of which have multiple foreign investors. Mexico has 24 projects with some foreign investment (71 per cent of its total), 13 of which have multiple foreign investors.

Overall, 49 per cent of projects with some foreign investment have multiple foreign investors. This includes investments by carbon funds that have participants from several countries. For 28 per cent of the projects with some foreign investment, the investment comes from a single Annex I country– the United States in the case of one-third of these projects. For the remaining 23 per cent of projects with some foreign investment, the investment comes from a single non-Annex I country, mostly (73 per cent) from Hong Kong.

The pattern of foreign investment for CDM renewable energy projects is complex. About half of the projects with foreign investment receive funds from multiple countries. When the investment comes from a single country, it is more likely – 28 per cent versus 23 per cent – to come from an Annex I country than a non-Annex I country. The largest individual flow is investment from Hong Kong in Chinese projects.

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[115] Based on data for the categories of renewable energy projects shown in Figure 15 – geothermal to wind.

[116] The deviations from the trends for renewable energy CDM projects and Annex I renewable energy projects are negatively correlated (-0.64) and have a statistically significant negative coefficient (-0.60) when regressed against each other. The same pattern holds when the share of foreign capital is calculated using total investment.

## 4.3. MITIGATION COSTS OF CDM PROJECTS

From the information contained in CDM project PDDs, it is possible to estimate mitigation costs for most projects. Essentially, the mitigation cost is the average cost of reducing emissions by one tonne of $CO_2$ equivalent for a project over its lifetime.[117] Mitigation cost is calculated (see Annex B) by taking the initial investment plus the net present value of the annual operational expenditures minus the annual revenues (e.g. income from electricity sales for wind projects) except those from the sale of CERs, divided by the expected number of CERs per annum.[118] The crediting period of the project rather than its operational lifetime is used for the calculation. Mitigation costs do not include CDM transaction costs which may be as low as USD 0.02 – 0.03 per CER for large projects and as high as USD 1.20 – USD 4.05 per CER for small projects.[119] On average transaction costs are less than USD 1 per CER.[120]

The project mitigation costs are sensitive to the project crediting period and less sensitive to the discount rate used[121]. There is substantially more variance in the mitigation costs for projects with a fixed crediting period relative to those with a renewable crediting period.

### 4.3.1. Project mitigation costs

Most CDM projects[122] with a renewable crediting period (up to 21 years) cost less than USD 10/t $CO_2$e and have an average mitigation cost of USD 0.4 /t $CO_2$e. Those projects with a shorter period in which to accrue CERs (a fixed crediting period of up to 10 years) cost substantially more on average (USD 7/t $CO_2$e) and most of them cost less than USD 40/t $CO_2$e. This is consistent with the findings of Castro (2010) and UNFCCC (2011).[123]

In addition to the large difference in mitigation costs between fixed and renewable crediting period projects, there are also large differences in mitigation costs between project types as shown in Table 5. On average solar projects are significantly more expensive than any other project type, followed by energy efficiency supply side, biomass energy and methane avoidance projects. At shorter crediting periods – solar projects have the highest mitigation cost overall, followed by energy efficiency supply side, wind, energy efficiency industry, fossil fuel switch and hydro projects. Irrespective of crediting period solar photovoltaic and solar thermal projects have an average mitigation cost of USD 326/t $CO_2$e and USD 200/t $CO_2$e respectively, whereas solar cooking and water heating projects are considerably cheaper at USD 3/t $CO_2$e and USD 2/t $CO_2$e respectively. In some cases projects have negative mitigation costs (see Section 4.3.3).

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[117] The units are the same as capital investment by project type in Figure 9, but are calculated differently. Capital investment by project type does not include all operating costs and all revenues other than the sale of CERs over the life of the project.

[118] As interest rates are generally positive, the net present value is the standard method used to discount future costs and benefits to current values.

[119] Gillenwater and Seres, 2011.

[120] Buen 2012; Antinori and Sathaye 2007; Wetzelaer et al., 2007.

[121] The mitigation cost was also calculated using the default values for expected return on equity as listed in “Guidelines on the assessment of investment analysis” (report of the 62nd CDM-Executive Board meeting, Annex 5), but no significant differences were found.

[122] Approximately two thirds of projects listed in Table 5.

[123] UNFCCC, 2011 used the mean as the measure of central tendency, which in this study is USD 2 /t$CO_2$e for renewable and USD 25 /t$CO_2$e for fixed crediting period projects. Due to the distribution of the mitigation cost data, where values are skewed and there are a small number of very high or low values, the median is a more appropriate statistic and is therefore used in this study.

Table 5. **Mitigation costs for renewable and fixed crediting periods by project type (USD/t$CO_2$ e)**

| | Renewable crediting period (up to 21 years) | | | Fixed crediting period (up to 10 years) | | | |
|---|---|---|---|---|---|---|---|
| **Project type** | **median** | **minimum** | **maximum** | **median** | **minimum** | **maximum** | **N** |
| Solar | 20 | 1 | 460 | 668 | 3 | 954 | 34 |
| Energy efficiency supply side | 4 | (0.3) | 9 | 28 | (10) | 167 | 8 |
| Biomass energy | 2 | (27) | 19 | 8 | (18) | 56 | 135 |
| Methane avoidance | 1 | (11) | 192 | 4 | (15) | 15 | 124 |
| Landfill gas | 1 | (4) | 12 | 2 | (3) | 29 | 99 |
| Wind | 1 | (11) | 440 | 28 | (17) | 137 | 727 |
| Hydro | 0.2 | (49) | 45 | 10 | (16) | 209 | 901 |
| Energy efficiency industry | - | - | - | 18 | 0.25 | 68 | 5 |
| Fossil fuel switch | (0.2) | (20) | 39 | 13 | (111) | 52 | 37 |
| Coal bed/mine methane | (0.1) | (1) | 3 | 1 | (4) | 6 | 46 |
| EE own generation | (1) | (7) | 3 | 3 | (12) | 61 | 124 |

Source: Based on the reported capital investment, operational costs and non-carbon revenues for 2,251 registered and registering projects as of June 2012. Not all project types are shown due to data paucity, N denotes the total number of observations per project type, and mitigation costs in parenthesis are negative.

### 4.3.2. Viability of CDM projects

It is tempting to compare the mitigation cost obtained here to with CER price in order to explore the profitability of CDM projects. That is, if CER prices are much higher than project mitigation costs, then the CDM project is likely to be profitable and hence attractive to investors. However, although project mitigation costs are a good measure of a project's costs over its lifetime, the metric ignores the baseline costs which can be significant for many projects. Baseline costs are required so that when subtracted from the mitigation costs the result can be compared to the CER price, to ascertain the relative profitability of projects.

Avoided baseline costs help make projects with a high mitigation cost economically viable. The mitigation costs of hydro, wind and solar projects with fixed crediting periods are relatively high, but they may defer investment in fossil-fired generation. The avoided investment in fossil-fired generation makes such renewable projects economically viable despite the high mitigation cost.

Although data on baseline costs are currently not available at a project-by-project level, a sense of the viability of some CDM projects (project types listed in Table 5) can nevertheless be gained by comparing the average mitigation cost for all projects with the market price for CERs during the past year. The CER price had fallen significantly from USD 12 in July 2011 to USD 5 in June 2012. During this time it was higher than the average mitigation cost of USD 0.5 /t $CO_2$e for projects with a renewable crediting period and perhaps on a par with projects with a fixed crediting period (USD 7 /t $CO_2$ e). However, there are many projects with higher mitigation costs or higher transaction costs, which may be more or less profitable without additional revenues or higher CER prices.

### 4.3.3. Interpretation of negative mitigation costs

Table 5 shows that there are some types of projects with a negative mitigation cost. A negative mitigation cost means the project is profitable without revenue from the sale of CERs.

It is natural to interpret a negative project mitigation cost as indicating that a project is not additional. Such an interpretation is incorrect for several reasons. First, a CDM project can be profitable without CER revenue but is still additional if the baseline scenario is more profitable. Although the number and types of project for which this is the case has not been analysed, numerous PDDs claim that the project scenario would not be chosen despite its profitability because a more lucrative option is available. Secondly, a CDM project can be profitable but still be additional if access to capital or other barriers restrict implementation. Many PDDs include detailed investment data, but document the existence of such barriers. Finally, the calculations assume that crediting periods will be renewed with the same baseline and projected emission reductions. If that does not happen, the mitigation costs will be higher than these estimates.

### 4.3.4. Other studies of the mitigation costs of CDM projects

Financial data from the PDDs for 840 projects submitted for validation during 2003-2008 are used by Rahman et al. (2009) to estimate mitigation costs for 10 project types – biogas; biomass; hydro; wind; geothermal; HFC, PFC and $N_2O$ reduction; methane, coal bed/mine methane and cement; supply-side energy efficiency; demand-side energy efficiency; and fossil fuel switch. The estimated marginal cost curves suggest economies of scale in emission abatement and cost differences by project type.[124] In particular, nitrogen and methane gas reduction projects are characterized by much lower marginal costs relative to wind or biomass projects.[125] The authors conclude that investors focus on projects with low mitigation costs, so the CDM market is operating efficiently and sending the right signals to the investors.[126]

Castro (2010) uses the mitigation costs to analyse whether CDM projects are capturing most of the low-cost emission reductions – the “low-hanging fruit” – in the host countries. That might raise the cost to those countries of meeting possible future mitigation targets.[127] She uses the mitigation costs and the projected annual emission reductions for all CDM projects proposed as at October 2009 to develop marginal abatement cost (MAC) curves for nine countries (Argentina, China, Indonesia, Israel, Malaysia, Mexico, Thailand, South Africa and Republic of Korea). The MAC curve ranks the project types in order of increasing cost and shows the estimated annual emission reductions for each type. With the lowest (often negative) cost option at the origin, the MAC curve rises step-wise as one moves to the right and adds progressively more costly project types. The MAC curves show the potential emission reduction that could be achieved for less than a specified cost per tonne of $CO_2$ equivalent.

Castro compares her MAC curves for CDM projects with published MAC curves of all emission reduction options for the year 2010 for six of the nine countries above (excluding Indonesia, Israel and Malaysia). She finds that the percentage of abatement potential captured by the CDM projects ranges from 1.8 per cent in South Africa to 30.9 per cent in China.[128] On the basis of these results, Castro concludes that there are still plenty of low-cost opportunities available. In other words the CDM is not capturing all of the identified abatement potential in these countries and the low-hanging fruit argument is weak.[129]

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[124] The marginal costs did not decrease over time. (Rahman et al., 2009, pp 16 and 17).

[125] Rahman, et al., 2009, p. 16.

[126] Rahman, et al., 2009, p. 16.

[127] Such an impact 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, the market power of the countries, and on the ability to bank credits from one commitment period to the next (Castro, 2010, pp. 8-9).

[128] Castro, 2010, table 1, p. 22. The figures for the other countries are: Mexico 2.1 per cent; Thailand 8.8 per cent; Argentina 17.6 per cent and Republic of Korea 17.7 per cent.

[129] Castro, 2010, p. 24.

An updated analysis of mitigation costs is provided by Rahman et al. (2012) for 6,700 projects submitted for validation through December 2010. Mitigation costs are estimated for eight project types – renewables; HFCs, PFCs and $N_2O$; methane avoidance; supply side energy efficiency; demand side energy efficiency; fossil fuel switch; transportation; and forest. Average mitigation costs differ by project type with forest projects being the most costly, followed in order of declining cost by demand-side energy efficiency, methane avoidance, supply-side energy efficiency, renewables, fossil fuel switch, transport, and HFCs, PFCs, and $N_2O$ reduction projects. Mitigation costs differ by region and change over time – generally declining, but not monotonically.[130] In contrast to the results presented in Section 4.3.1, the analysis also finds that the crediting period does not have a significant effect on mitigation cost.[131]

As in their earlier study, Rahman et al. (2012) find that CDM projects exhibit economies of scale – lower mitigation cost per tonne of $CO_2$e for larger projects – although they vary by project type. Forest, renewable and transport projects exhibit relatively large economies of scale; fossil fuel switch and HFCs, PFCs, and $N_2O$ reduction projects have virtually no economies of scale; while demand-side energy efficiency, supply-side energy efficiency, and methane avoidance projects exhibit diseconomies of scale – higher mitigation cost per tonne of $CO_2$e for larger projects – beyond 350, 1,850, and 3,050 Kt $CO_2$ e/year respectively.[132]

## 4.4. REVENUE FROM THE SALE OF CERS

CDM project owners sell CERs to buyers in Annex I countries. The revenue from the sale, less transaction costs, accrues to the project owners most of whom are based in developing countries.[133] The revenue generated by the sale of CERs is estimated using the quantity of CERs transferred from the CDM registry – transferred to the buyer – and information on CER prices. Precise information on CERs transferred from the CDM registry is available by project and year. Over 750 million CERs had been transferred to the international transaction log from the CDM registry by the end of 2011. This was over 92 per cent of the CERs issued over the same period.[134]

Some projects enter into an emission reduction purchase agreement (ERPA), before the project is registered, to sell some of their CERs. A transaction pursuant to such an agreement is called the primary market. Prices are relatively low as the buyer accepts some risk that the CERs will not be delivered; if for example the project is not registered. An ERPA may involve an initial payment, but most payments are believed to be tied to the delivery of CERs. CERs issued that are not part of an ERPA can nevertheless be sold to a prospective buyer. Such transactions occur on the secondary market. Prices on the secondary market are higher as the CERs can be transferred immediately hence there is practically no risk of non-delivery.

Figure 17 shows the estimated revenue from the sale of CERs by year from 2007 through 2011 valued at the primary and secondary market prices in millions of United States dollars.[135] The total revenue for this period is estimated at USD 9.5 billion (primary market prices) and could be as high as USD 13.5 billion (secondary market prices).[136] Prices on both markets rose between 2007 and 2008 and have fallen steadily since then. Thus most of the fluctuations in revenue are due to changes in the number of CERs transferred. The number of CERs transferred fell from 195 million in 2008 to 113 million in 2010 before jumping to 299 million in 2011. Estimates of the revenue from the sale of CERs by host country are provided in Tables A-7 and A-8.

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[130] Rahman et al., 2012, Table 4.

[131] Rahman et al., 2012, p. 29.

[132] Rahman et al., 2012, p. 27.

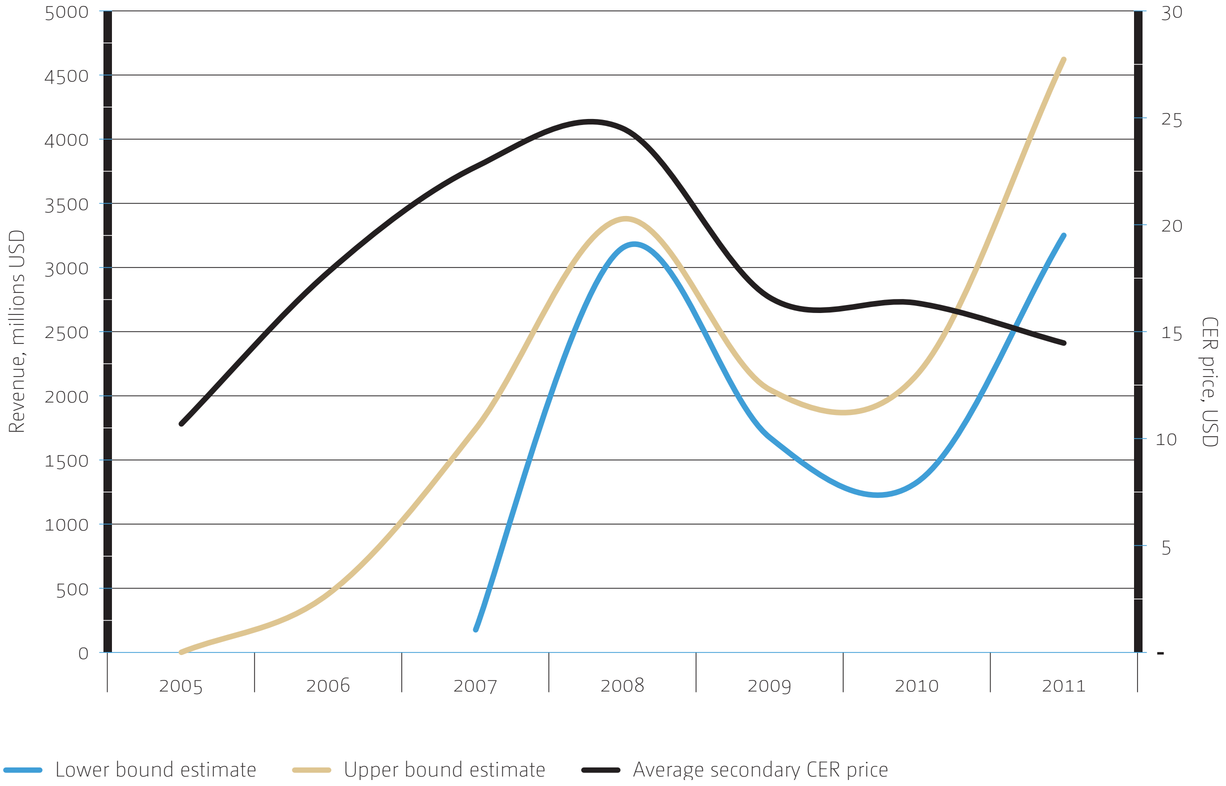
[133] Most investment in CDM projects comes from the host country, so most project owners (participants that made the investment) are developing country residents.

[134] Over 815 million CERs issued by the end of 2011. Both the issuance and transfer figures exclude CERs collected as the share of proceeds for the Adaptation Fund.

[135] Primary CER prices and secondary CER prices for 2007 through 2009 calculated from quantity and value data in various issues of State and Trends of the Carbon Market. Secondary CER prices for 2010 and 2011 are weighted averages of monthly spot CER prices reported by Tendances Carbone converted to USD using exchange rates of 1.325 and 1.3914 respectively

[136] The revenue to project owners would be lower by the transaction costs, less than USD 1 per CER for 750 million CERs.

Figure 17. **Estimated revenue from the sale of CERs by year (million US dollars)**



Source: Calculated using data on CERs transferred from the CDM registry to the international transaction log by year and annual average primary and secondary market prices for CERs.

## 4.5. COMPLIANCE COST SAVINGS FOR ANNEX I PARTIES

The CDM can assist Annex I Parties to reduce their compliance costs in two ways. First, a government can choose to purchase CERs (and other compliance units) instead of implementing policies to achieve more costly domestic reductions. Second, where permitted by the national government, entities subject to a domestic policy can use CERs (and other compliance units) to comply with the policy. The government then uses the CERs purchased by entities to offset the higher domestic emissions. For example, installations in the European Union Emissions Trading System (EU ETS) and Japanese firms with voluntary commitments can use CERs for compliance. Compliance use by installations in the EU ETS is the dominant use to date – almost half of the CERs issued to 31 March, 2012.

The cost savings already realized by installations in the EU ETS are estimated first. These are then extrapolated to cover CER use to-date by Japanese firms. Finally, a crude estimate of the cost savings to Annex I parties due to the use of CERs by both firms and governments for the 2008–2012 commitment period is developed.

### 4.5.1. Compliance cost savings due to CER use by installations in the EU ETS

Each year installations in the EU ETS must submit valid compliance units – European Union Allowances (EUAs), CERs or Emission Reduction Units (ERUs) – equal to their actual emissions during the previous year. EUAs equal to the annual emissions cap are distributed each year, mostly through free allocation to participating installations. EUAs, like CERs, can be freely traded. CERs have a lower market price than EUAs but both are equivalent for compliance, so using CERs reduces compliance costs. Using CERs also reduces demand for EUAs which also lowers the market price of EUAs.

Thus, a lower bound estimate of the compliance cost saving to EU ETS installations resulting from the use of CERs can be calculated from the difference in the market prices of CERs and EUAs and the quantity of CERs used for compliance. The quantity of CERs used for compliance each year is known. The EUA-CER spread changes daily and has varied widely over time from less than €1 to over €5.[137] The estimated cost savings, then, depend on the price spread used for the calculation. The relevant price spread is the one on the day installations must decide which EUAs and CERs to submit for compliance; 30 April of the subsequent year. Since both EUAs and CERs can be banked for use in future years, the spread at the time the compliance decision is made best reflects the value of the savings to the installation.

The estimated compliance cost saving for EU ETS installations for the years 2008 through 2011 due to the use of CERs is calculated in Table 6. The total saving over the four years is almost €1.2 billion (USD 1.5 billion). Both the number of CERs used for compliance and the EUA-CER price spread have generally increased over time. Greater use of CERs for compliance has been made possible by the growth in the number of CERs issued. For 2008 and 2009 compliance use represented about 75 per cent of the CERs issued prior to the compliance deadline. By 2011 cumulative use had fallen to about half of the CERs issued. In 2010 the European Union announced that installations will no longer be able to use CERs from HFC and $N_2O$ projects after 2012, so there was an incentive to use CERs from such projects during 2010, 2011 and 2012. This accounts for some of the growth in CER compliance use during 2010 and 2011.

Table 6. **Estimated savings due to compliance use of CERs by EU ETS installations** [138]

| Year | CERs Used (million) | EUA-CER spread (€)* | Saving (million € ) |
|---|---:|---:|---:|
| 2008 | 82.5 | 1.90 | 156.8 |
| 2009 | 77.9 | 1.34 | 104.4 |
| 2010 | 116.9 | 3.19 | 372.9 |
| 2011 | 178.8 | 3.07 | 548.9 |
| **Total** | **456.1** | | **1,183.0** |

Note: * Price spread on 30 April of the subsequent year.

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[137] The price spread on a given day reflects expectations about the future supply of and demand for EUAs and CERs. Profits or losses due to sales of EUAs and CERs are due to trading activity and are not related to compliance.

The increased EUA-CER spread is driven by reduced emissions and the cap on CER compliance use by EU ETS installations. The recession during 2009 and 2010 reduced emissions by EU ETS installations, reducing the demand for EUAs, CERs and other compliance units (ERUs).[139] Growth in the issuance of CERs (and ERUs) has increased the supply of compliance units. As a result prices have fallen. The price of EUAs has fallen from €24.11 on April 30 2008 to €6.94 on 30 April 2012.[140] The price of CERs has fallen more – the EUA-CER spread has increased – because compliance use of CERs and ERUs is capped and the EU announced that this cap will apply through 2020.[141] Thus the demand for CERs for compliance use by EU ETS installations is fixed while the supply is increasing.

Although difficult to measure, the availability of CERs increases the overall pool of compliance units and hence lowers the market price of EUAs. The price of EUAs fell by over €17 between 30 April 2008 and April 30, 2012. During that period over five billion EUAs had been used for compliance by EU ETS installations. An estimate of the savings due to the impact of CERs on the price of EUAs would require significant modelling work. As an illustrative calculation, if even €1 of the price decline has been due to the availability of CERs, then the CDM would have reduced compliance costs by a further €5 billion (USD 6.5 billion). Thus, the cost savings due to the impact on the price of EUAs could be much larger than the savings due to the use of CERs for compliance.

### 4.5.2. Cost savings due to CER use by Japanese firms

Use of CERs by Japanese firms to meet their voluntary commitments is estimated at 36 million CERs to-date. There is no market price that can be used to estimate a price spread and hence cost savings for compliance use of CERs by Japanese firms. Assuming that the cost saving is the same as for installations in the EU ETS, this yields an estimated compliance cost saving of €92 million (USD 120 million).[142]

### 4.5.3. Compliance cost savings by firms and governments for 2008–2012

For the 2008–2012 commitment period, it is estimated there will be cost savings to Annex I Parties due to the use of CERs by both firms and governments. Installations in the EU ETS probably will use as many CERs for 2012 compliance as for 2011 compliance as CERs from HFC and $N_2O$ projects will no longer be accepted after 2012. The EUA-CER price spread may also widen since the quantity of CERs issued is rising while the use of CERs for compliance through 2020 is capped.[143] Thus, assuming that the compliance cost savings for 2012 are the same as those for 2011, €548.9 million (USD 715 million), is probably conservative. That would bring the total savings to €1.7 billion (USD 2.3 billion).

Assuming that the savings to Japanese firms are equal to the annual average for 2008-2011 would raise the total saving from €92 million (USD 120 million) to about €115 million (USD 150 million) for the commitment period.

Government use of CERs, ERUs and purchased Assigned Amount Units (AAUs) to help achieve compliance with their 2008–2012 emissions limitation commitments by Japan and several European countries is projected at 500 to 600 million units (Kossoy and Guigon, 2012, Table 5).[144] Most of this demand is likely to be met by CERs. To calculate the cost savings would require information on the costs of the domestic policies each country would have implemented in lieu of the CER purchases as well as the cost of the CERs purchased.

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[138] Trotignon (2011) estimates the savings for 2008 and 2009 at €283 million (range €100 to €546 million) compared to €261 million here. Trotignon uses the average of the daily spreads and the minimum and maximum daily spreads for the range. He also had higher compliance use – 170.4 million for the two years compared with 160.4 million here.

[139] ERUs are emission reduction units issued for emission reductions in developed countries. They can be used for compliance by EU ETS installations.

[140] 30 April prices for 2008 through 2012 are as follows: €24.11, €12.92, €14.25, €16.27 and €6.94.

[141] The cap – about 1,450 million -- covers use of both CERs and ERUs, but the supply of CERs is much larger than the supply of ERUs – 919 million CERs and 143 million ERUs as of 30 April, 2012.

[142] The saving for EU ETS installations is €2.56 per CER (€ 1,166.9 million/456.1 million CERs from Table 5), so the saving for 36 million CERs is €92 million.

[143] Proposals to temporarily reduce the quantity of EUAs issued or to set a minimum price for EUAs also would tend to increase the EUA-CER price spread.

[144] Actual use of CERs will not be known until compliance with national emissions limitation commitments for 2008–2012 is assessed, probably in 2014.

European Union (EU) member States are expected to account for most of the government use of CERs to meet 2008-2012 national commitments. Use of purchased CERs allows these countries to avoid implementing more costly domestic mitigation options. The cost of the avoided options likely would exceed the price of EUAs which reflects the cost of domestic options being implemented. Thus, the EUA-CER spread, €2.56 per CER, probably is a conservative estimate of the cost saving due to government use of purchased CERs. Assuming that Annex I governments use approximately 400 million CERs for compliance the estimated savings are approximately €1 billion (USD 1.3 billion).[145]

### 4.5.4. Summary of compliance cost savings

In summary, the CDM has reduced compliance costs for firms in the EU ETS and Japan by at least USD 1.6 billion for the period 2008 through 2011.[146] For the 2008–2012 commitment period the compliance cost savings for these firms are estimated to be at least USD 2.3 billion. Annex I government use of CERs to meet their national emissions limitation commitments will yield an additional USD 1.3 billion in savings. The total lower bound estimate on compliance savings to Annex 1 Parties and their institutions due to the existence of the CDM is USD 3.6 billion. The savings are likely much larger depending on the impact of CER use on the price of EUAs.

## 4.6. SUMMARY

The total investment in registered or registering CDM projects as of June 2012 is estimated at USD 215.4 billion. The annual investment peaked in 2008 at USD 13.9 billion (operating projects) and USD 40.4 billion (all projects), but the large number of projects undergoing validation could lead to a new, much higher, peak in 2012 or thereafter.

The average investment per project is approximately USD 45 million. China and India account for 65 per cent of the total investment with 45 per cent of the projects. Projects in East Asia have relatively large capital investment due to the capital-intensive (capital investment per MWe of capacity) nature of the projects undertaken (renewables) and their large average size. In contrast, the capital investment per project of almost every other region is equal to or below the overall average. A comparison of renewable energy CDM projects with similar projects in Annex I countries shows that CDM projects are often much larger and less capital-intensive (lower cost per MWe of capacity) than corresponding projects in Annex I countries.

Approximately 90 per cent of CDM projects and 65 per cent of similar renewable energy projects in Annex I countries are domestically financed. However, there is a strong indication that the share of foreign investment is increasing in both CDM and Annex I projects. The pattern of foreign investment in CDM projects is complex, with funds coming from both developed and developing countries and often from multiple countries for a single project. Indications are that foreign investment available for renewable energy projects may shift between non-Annex I and Annex I projects as conditions in these countries change.

Most CDM project types have an average estimated mitigation cost below 10 USD per tonne of carbon dioxide equivalent (t $CO_2e$). These costs vary significantly by project type, with solar being the most expensive technology deployed in the CDM (>300 USD/t $CO_2e$). The average mitigation cost has increased over time, which reflects the change in the mix of project types with fewer low-cost industrial gas projects in recent years. However, it may also reflect a more stringent assessment of additionality over time leading to fewer project activities that are economically viable without the revenue from the sale of CERs.

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[145] CERs are expected to account for most of the 500 to 600 million units projected to be purchased and used for compliance by Annex I Parties.

[146] CERs have also been used for compliance in New Zealand – 133,150 for 2010 (6 months) and 4,150,189 for 2011. Unlimited imports of CERs (and other units) are permitted in New Zealand, so the price difference between CERs and New Zealand Units (NZUs) is small (approximately NZD 0.10). Calculating the compliance cost saving on the basis of the CER – NZU price spread yields an estimate of less than USD 0.5 million. The decline in the price of CERs has contributed to the decline price of NZUs. The compliance cost saving due to this effect is probably much larger.

Many project activities have a negative mitigation cost i.e. show profitability without revenue from CERs, but this does not necessarily mean the project is not additional. The expected mitigation costs estimated here do not account for avoided project baseline costs – the fossil-fired generation displaced by a wind project for example – and this may be critical to the economic viability of some project activities. There are indications from projects that have no baseline costs, that CDM projects are still profitable. Rising mitigation costs and falling CER prices may however impact the viability of many projects thereby reducing the influx of new entrants to the CDM.

There is evidence of economies of scale – lower mitigation cost per tonne of $CO_2$e for larger projects – for some types such as renewable, forestry and transport projects, and diseconomies of scale – higher mitigation cost per tonne of $CO_2$e for larger projects – for others such as demand-side energy efficiency, supply-side energy efficiency, and methane avoidance project activities.

Over 750 million CERs had been transferred from the CDM registry by the end of 2011. The revenue generated by the sale of these CERs is estimated to be at least USD 9.5 billion and possibly as much as USD 13.5 billion.

Savings for Annex I countries through the use of CERs are estimated to be at least USD 3.6 billion for 2008 to 2012. The CDM is projected to reduce compliance costs for firms in the European Union Emissions Trading System and in Japan by at least USD 2.3 billion for the period 2008 through 2012. The estimate is based on the difference between CER prices and EUA prices. Since CERs also had the effect of lowering the price of EUAs, the estimate understates the savings. The use of CERs by Annex I governments to meet their 2008 to 2012 national emission limitation commitments is expected to yield an additional USD 1.3 billion in savings.

Other studies suggest that investors focus on projects with low abatement cost so the CDM market is working relatively efficiently. They also suggest, however, that there is still significant untapped potential for CDM projects even in countries with many CDM project activities.

# V. REGIONAL DISTRIBUTION OF CDM PROJECTS

The Kyoto Protocol does not prescribe how CDM projects should be distributed among host countries, but interest in regional distribution patterns so that all countries benefit from the CDM has been high since well before the first project was registered (Ellis and Kamel, 2007; Lütken, 2011). In June 1998, the G77 and China posed the question, "How to ensure that CDM projects are equitably distributed so as to benefit all developing country parties, in particular the least developed country parties ..." (UNFCCC, 1998). Questions about the regional distribution of CDM projects have been raised at almost every session of the Conference of the Parties serving as a Meeting of the Parties to the Kyoto Protocol (CMP).

Assessing the distribution of CDM projects requires a benchmark – an equitable regional distribution – against which the actual distribution of CDM projects can be compared. Neither the CMP nor researchers have defined "equitable regional distribution." It is possible to document the regional distribution of CDM projects (Section 5.1). It is also possible to analyse factors that influence the regional distribution of CDM projects (Section 5.2).

## 5.1. CURRENT DISTRIBUTION OF CDM PROJECTS

Many developing countries do not have any registered CDM projects. As shown in Table 7, as of June 2012, 21 countries have no CDM projects simply because they do not have a Designated National Authority (DNA). Some high income countries (e.g. Antigua and Barbuda, Bahrain, Brunei Darussalam, Kuwait, Trinidad and Tobago) may have less interest in CDM projects. Implementing CDM projects in countries affected by domestic unrest and civil war (e.g. Afghanistan, Chad, Iraq, Mauritania) may also be difficult.

Of the 129 countries with a DNA, 50 do not yet have a registered CDM project. Twenty seven of 48 African countries with a DNA do not have a registered CDM project, and 25 of 41 least developed countries (LDCs) with a DNA do not have a registered CDM project.

Table 7. **Regional distribution of CDM projects registered and undergoing registration**

| Region | Countries without a DNA & zero projects | Countries with a DNA & zero projects | Countries with 1-10 projects | Countries with 11-100 projects | Countries with >100 projects | Total countries |
|---|---|---|---|---|---|---|
| Africa (33) | 5 | 27 | 18 | 3 | 0 | 48 |
| Asia & Pacific (13) | 11 | 11 | 17 | 7 | 2 | 37 |
| Europe & Central Asia | 1 | 4 | 8 | 1 | 0 | 13 |
| Latin America & Caribbean (1) | 4 | 8 | 12 | 7 | 2 | 29 |
| China & India | 0 | 0 | 0 | 0 | 2 | 2 |
| Total | 21 | 50 | 55 | 18 | 6 | 129 |
| LDCs | 6 | 25 | 15 | 1 | 0 | 41 |

Source: Projects registered and undergoing registration excluding projects rejected, withdrawn or undergoing validation, as of June 2012. The numbers of LDCs in a region are in parenthesis.

Differences in level of CDM participation are even more pronounced when measured in terms of the share of CERs by region. As shown, both Africa and the LDCs have only 1 to 3 per cent of the CERs. Their shares are still as small when considering only small-scale projects and when projects to reduce industrial gases are excluded.[147] Africa's share of expected CERs from future projects – projects at validation – is somewhat higher (5 per cent), but the LDCs' share of expected CERs from projects at validation is still only 2 per cent.

Table 8. **Share of CERs from projects registered and undergoing registration by region**

| Region | Total | Small scale projects | Large scale projects | Non industrial gas projects | Projects undergoing validation |
|---|---|---|---|---|---|
| Africa | 3% | 2% | 3% | 3% | 5% |
| Asia & Pacific | 10% | 23% | 9% | 10% | 10% |
| China | 68% | 41% | 70% | 67% | 57% |
| India | 7% | 19% | 6% | 8% | 12% |
| Europe & Central Asia | 1% | 0% | 2% | 2% | 1% |
| Latin America & Caribbean | 11% | 15% | 10% | 11% | 14% |
| LDCs | 1% | 2% | 1% | 1% | 2% |

Source: Projects registered, undergoing registration and undergoing validation as of June 2012. Percentages are of total CERs projected over the full crediting period for all projects. Non-industrial gas projects excludes those projects that reduce HFCs, $SF_6$ and PFCs.

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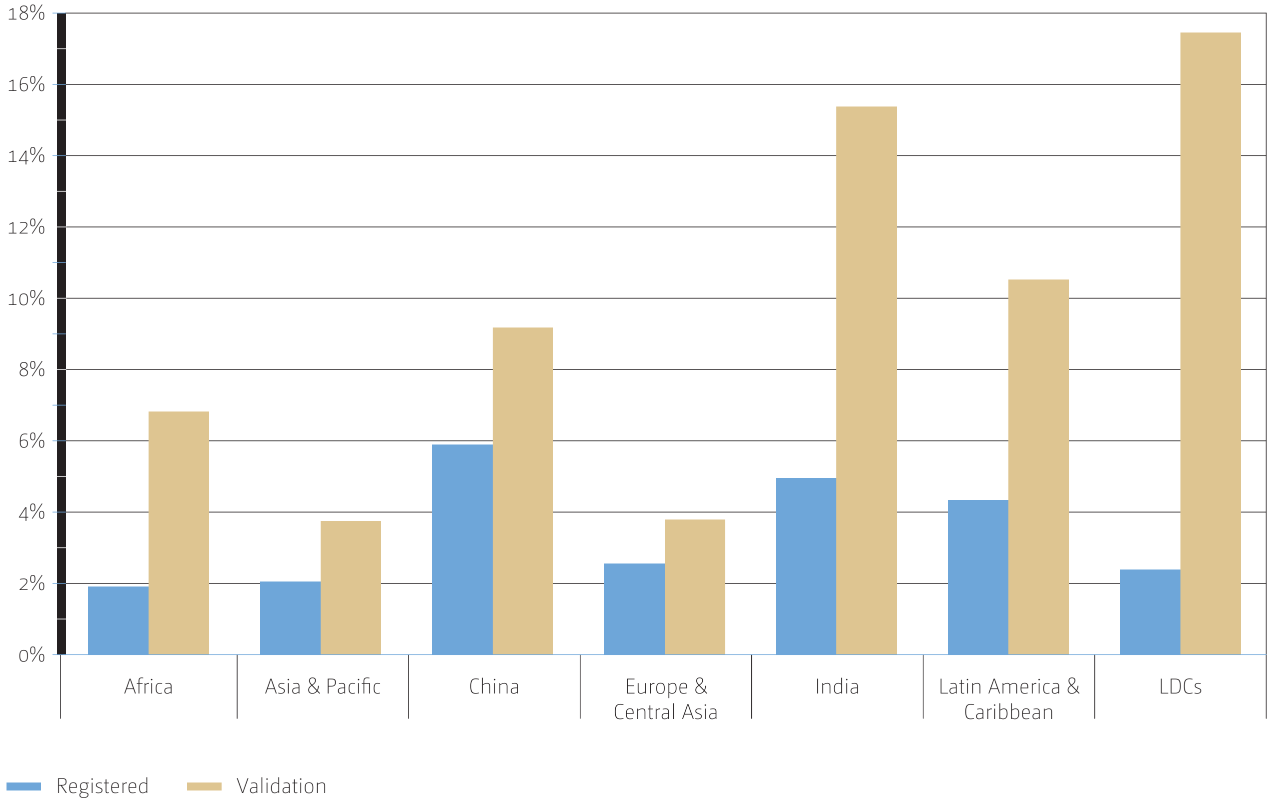
[147] It is expected that there is a low potential for industrial gas (HFCs, $SF_6$ and PFCs) projects to be implemented in Africa or LDCs.

CER production as a share of national emissions is another measure of CDM participation (Lütken, 2011). For registered projects Africa and LDCs have the lowest shares – CERs equal to about 2 per cent of national emissions (Figure 18). In contrast, the CERs from registered projects represent about 5 and 6 percent of national emissions respectively for India and China.[148]

However, when projects undergoing validation are included the pattern changes somewhat. The share of national emissions is higher in LDCs than in other regions, largely because of their relatively low emissions. Africa's position also improves relative to other regions when projects at validation are included again due to the relatively low emissions of African countries.

Figure 18. **CERs as a share of national $CO_2$ emissions**



Source: CERs from projects registered, undergoing registration and validation, but excludes projects rejected and withdrawn as of June 2012. CERs are annual CERs, as stated in the PDDs which include non-$CO_2$ gases ($CH_4$, $N_2O$, HFCs, PFCs, $SF_6$). National $CO_2$ emissions for 2010 are from the WRI (http://www.wri.org), but do not include emissions of non-$CO_2$ gases. This omission does not change the overall finding.

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[148] Excluding the CERs from registered HFC, PFC and $SF_6$ projects does not change the distribution shown in Figure 18 significantly.

## 5.2. DRIVERS OF REGIONAL DISTRIBUTION

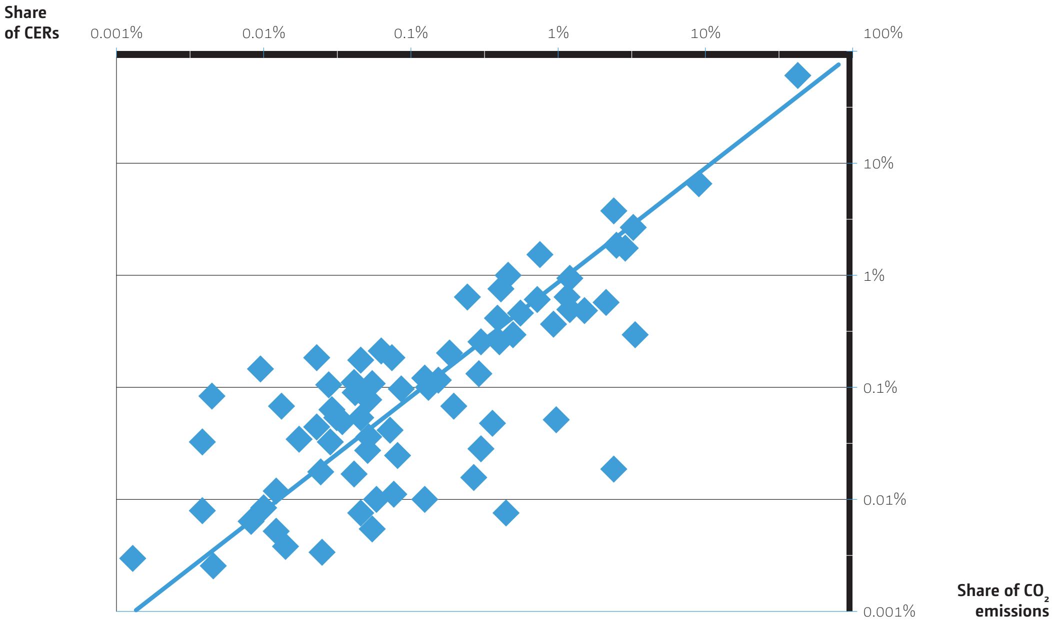
Several studies have attempted to identify the factors that influence the regional distribution of CDM projects. Studies attempt to identify factors that influence whether a country hosts a CDM project and/or factors that influence the scale of CDM activity, i.e. the number of projects or the projected emission reductions. A few studies (Dinar et al., 2008; Flues, 2010) distinguish unilateral projects from projects with Annex I participants.

### 5.2.1. National emissions

Winkelman and Moore's (2011) statistical analysis finds that the host country's national emissions or mitigation potential are the most important determinant both of whether a country hosts CDM projects and the scale of CDM activity. The carbon intensity of the economy and cumulative experience with the CDM also affects the scale of CDM activity. Lütken's (2011) analysis shows similar results. Other indicators of mitigation potential – energy structure (Dinar et al., 2008) and economic growth (Flues 2010) – corroborate the role of mitigation potential in determining the distribution of CDM projects. Many analysts have noted that, as a market-based mechanism for initiating low cost emissions reductions, most CDM projects – or more specifically most of the CERs – would be located in countries where significant GHG emissions can be reduced or avoided at relatively low cost.

The relationship between share of non-Annex I $CO_2$ emissions by country and the share of CERs from registered projects is clear and statistically significant (Figure 19).[149] Other variables such as GDP and FDI as a share of GDP also have explanatory power, but not as large as the share of $CO_2$ emissions (although emissions and GDP are correlated in most countries).[150] The countries below the line (i.e. higher share of emissions relative to share of CERs) include many of the oil-producing and/or wealthier countries where interest in CDM may be lower. Furthermore, studies of barriers to projects in Africa and LDCs cite low national emissions as a key factor (Okubo and Michaelowa, 2010; Castro and Michaelowa 2011; Ellis and Kamel, 2007; Gillenwater and Seres, 2011).

Figure 19. **Share of CERs from registered projects versus share of non-Annex I country $CO_2$ emissions**



Source: Projects registered and undergoing registration, excluding projects rejected, withdrawn or undergoing validation as of June 2012. CERs are summed over the full crediting period of all projects, not adjusted for any potential changes due to the renewal of the crediting period. $CO_2$ emissions are from fossil fuel combustion and cement.

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[149] The $R^2$ parameter of share of $CO_2$ emissions versus share of CERs is 0.98.

[150] The $R^2$ parameters for share of GDP and share of FDI versus shares of CERs are 0.87 and 0.94, respectively.

It is clear that there is a positive relationship between the number of CDM projects in a country and its national emissions. What is less clear is if that relationship is causal. Several other analyses find significant potential for emissions reductions in Africa. A study of the mitigation potential in the energy sector of sub-Saharan Africa identified more than 3,200 projects reducing 740 $mtCO_2$/year using only existing approved CDM methodologies (de Gouvello et al., 2008). A recent update for 11 countries and 16 energy sector-related technologies estimates a technical mitigation potential of 128 $mtCO_2$/year (Arens, Burian, et al., 2011). Both of these studies focus on technical potential so they overestimate the CDM potential (Spalding-Fecher et al., 2004), but they suggest that factors other than low national emissions contribute to the relative lack of CDM projects in Africa.

### 5.2.2. Investment climate

It is evident from the sections above that most of the investment in CDM projects originates in the host country, so the investment climate in the host country is a crucial determinant of CDM activity (Michaelowa and Buen, 2012). Analysts use a variety of indicators for the host country investment climate including ease of doing business, political freedom, and corruption levels as important influences (Dinar et al. 2008; Flues 2010: Okubo and Michaelowa 2010; Burian et al. 2011; Ellis and Kamel 2007)[151].

The funds available for domestic investment also affect CDM activity. This was measured by gross fixed capital formation (Flues, 2010) and, indirectly, by the size of the economy, economic growth and energy sector growth (Winkelman and Moore 2011; Michaelowa and Buen 2012).

To test if country characteristics influence whether a CDM project is initiated in a country or not, a simple analysis of the relationship between the number of CDM projects and various country characteristics was undertaken (see Annex B). The results suggest that the number of operating CDM projects in a country is strongly dependent on the host country's national GHG emissions (95 per cent). However, it is also strongly dependent on the host country's gross savings (93 per cent), population and GDP (87 and 85 per cent respectively). Results also show that national GHG emissions, gross savings, population and GDP are strongly related to each other so it is difficult to pinpoint, which of these will influence CDM activity.

These findings are consistent with other studies which also show that a weak financial sector and/or limited supply of funds for domestic investment limits CDM activity in many African countries and LDCs (Castro and Michaelowa, 2011; Byigero et al., 2010; Schmidt-Traub, 2011; Burian et al., 2011; Michaelowa and Buen, 2012). The strength of the sectoral regulatory and policy environment in CDM relevant sectors also affects the investment climate (Castro and Michaelowa 2011; Burian et al., 2011; Arens, Wang-Helmreich et al., 2011; Michaelowa and Buen, 2012). The supply of funds for domestic investment is an area which should be addressed more fully by CDM capacity-building programmes (Okubo and Michaelowa, 2010; Ellis and Kamel, 2007; Castro and Michaelowa, 2011).

### 5.2.3. National CDM capacity

National CDM capacity is another significant determinant of CDM activity, although researchers have noted that while it is necessary, it is not sufficient a factor for attracting CDM projects (Okubo and Michaelowa, 2010; Castro and Michaelowa, 2011; Byigero et al., 2010; Burian et al., 2011; Arens, Wang-Helmreich, et al., 2011). A DNA is a precondition for CDM projects and at least 20 developing countries do not have a DNA.

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[151] See also the country ratings from Point Carbon, that raise similar issues <http://www.pointcarbon.com/research/carbonmarketresearch/cdmhostcountryrating/historicratings/>

Lack of awareness of the CDM in the financial sector and lack of local CDM consulting capacity may also be a barrier (Arens, Wang-Helmreich, et al., 2011). One or two projects often provide a good foundation for additional CDM activities. They build awareness and private sector capacity that can help develop more projects (Okubo and Michaelowa, 2010; Winkelman and Moore, 2011; Burian et al., 2011; Arens, Wang-Helmreich, et al., 2011).Finally, the lack of capacity and experience with the CDM make it more difficult for countries with only a few projects to cope with the CDM system complexity and rule changes (Platanova-Oquab et al., 2012).

## 5.3. SUMMARY

As a market mechanism, the distribution of CDM project activities and CERs has generally matched the distribution of mitigation potential and capital availability across countries. Although the number of host countries continues to grow, many countries with small economies and low GHG emissions have few, if any, CDM projects. These include many countries in Africa and the LDC group, as well as some in Asia. Various initiatives, both under and outside the Kyoto Protocol, have been implemented with the aim of increasing the number of CDM projects in such countries. It is too early to assess whether they have been successful.

The investment climate is critical for the distribution of projects among host countries. Having a strong institutional capacity for the CDM is necessary but not sufficient to attract projects. As many CDM project activities are domestically financed, a lack of access to early stage seed funding for CDM costs and high unit transaction costs are significant barriers in many poorer countries. The lack of underlying project finance prevents CDM projects from moving ahead in under-represented countries.

# VI. OPPORTUNITIES FOR IMPROVEMENT

This study summarizes the research on the benefits of the CDM to host countries, including claimed contributions to sustainable development, investment and technology transfer. It also includes an estimate of the cost savings to Annex I Parties to the Kyoto Protocol. Finally, the regional distribution of CDM projects is discussed. The research on these topics and other benefits of the CDM can be improved.

Our understanding of the sustainable development contribution of CDM projects will not improve so long as the primary source of information is the PDD claims and researchers continue to use different sustainable development indicators. A set of indicators that can capture all of the benefits claimed for CDM projects in a consistent fashion is an essential starting point. The indicators used in this and earlier studies do not fully meet this requirement. Further analysis of the PDD claims and survey responses can help identify indicators whose descriptions appear to be unclear. A revised set of indicators could be developed, subjected to expert review and public comment, and tested through a survey.

The PDD claims relating to sustainable development need to be related to the project's actual impacts. The accuracy of survey responses about actual sustainable development impacts is not known. But there are reasons to be sceptical, since consistent interpretation of 10 to 15 sustainable development indicators by participants in hundreds, ideally thousands, of projects would be difficult to achieve. The responses available so far suggest that the PDD information does not provide a comprehensive picture of the sustainable development impacts of CDM projects. Moreover, there is virtually no information on the potential sustainable development benefits of the baseline scenario. Some project types will have no sustainable development benefits in the absence of the CDM project, but others, such as renewable energy projects, may have. This further clouds the picture of the CDM's precise impact on sustainable development.

Research is needed to explore the potential sustainable development benefits of the CDM project baseline scenario. A top-down approach could be taken to assess the benefits that may occur in the absence of the CDM project by looking at project types, or a bottom-up approach may be used to look at individual projects. In addition, some ex-post assessment of the sustainable development impacts of CDM projects, and their relationship to the PDD claims and survey responses, is needed. Gold Standard projects, which require monitoring of their sustainable development impacts, may provide such information. However, ex-post assessment of the impacts of other projects would be useful as well because some of the project types believed to make the least contribution to sustainable development cannot qualify as Gold Standard projects. With more information on the baseline scenario and ex-post assessments, a better picture of how the CDM has assisted the sustainable development of host countries could be attained.

Technology transfer via the CDM has been analysed, extensively mainly on the basis of PDD claims. Follow-up surveys indicate that the PDD claims for technology transfer and no technology transfer are reasonably (close to 90 per cent) accurate. The analyses confirm that the CDM contributes to technology transfer. They also find that technology transfer is a complex, dynamic process that varies by technology and recipient country. Consensus on the recipient (CDM host) country characteristics that influence the rate of technology transfer has not yet been achieved. Replication of available analyses with more projects may allow those characteristics to be identified and how technology transfer under the CDM may also prompt parallel technology transfer processes outside of the CDM.

Another approach, only applied to wind projects so far, is to use patent data as a measure of technology transfer via all channels and to analyse whether the CDM contributes to technology transfer. That approach may also be able to identify recipient country characteristics that influence the rate of technology transfer. This approach could be applied to about a dozen technologies where a reasonable match between patent classes and CDM project types is possible. Such analyses may yield insights into the roles of different technology transfer channels including CDM, foreign direct investment and trade.

Investment in CDM projects is estimated using information provided in PDDs. The accuracy of that information is not known. Comparison of the PDD figures with the actual capital investment of a sample of projects would be very useful. Some project developers probably consider the actual capital investment confidential information, so such a comparison would probably need to be done on a confidential basis. However, results could be reported by project types; for example, that the investment in hydro projects is greater than the estimates reported in the PDDs. Data on actual capital investment might be obtained from funds that invest in CDM projects or as part of the verification process for a sample of projects.

Carbon funds are a source of foreign investment for CDM projects. Only 29 of 96 carbon funds in 2010 published financial information. Those funds had total capital of €10.8 billion (USD 14 billion) of which a maximum of 38 per cent was invested in CDM projects. Scaling that number up to all 96 funds provides an estimated foreign investment of almost USD 18 billion in CDM projects. Albeit a rough estimate, it suggests that carbon funds may be a significant source but not the sole source of foreign investment for CDM projects. Further work is required to determine the sources of funding of CDM projects and shifts in funding between non-Annex I and Annex I project investment.

Many types of renewable energy CDM projects have a lower capital intensity – average capital investment per unit of capacity (USD/MWe) – than similar Annex I projects. Confirmation of this difference and an examination of the reasons for this would be useful. The reasons could include economies of scale – CDM projects are larger – or lower costs in developing countries.

Many PDDs include sufficient information to estimate the mitigation cost. Again, the accuracy of the information is not known and a comparison of the PDD figures with the actual costs would be very useful for a sample of projects. Some project types with high mitigation costs may be economically viable due to avoided baseline costs. Analysis of underlying factors that may explain increasing mitigation costs, in particular for solar projects, is needed, as are analyses of the impact of avoided baseline costs on mitigation costs.

Some results from different analyses contradict one another, including whether or not the discount rate has a significant impact, the effect of the crediting period on mitigation costs, the trend in mitigation costs, and the presence or absence of economies of scale. An effort to reconcile the divergent results would improve understanding of the key factors that affect mitigation costs. Once the mitigation costs of CDM projects are better understood, a comparison with the mitigation costs of similar Annex I projects would be useful to inform the debate on the design of future market instruments. Analyses of baseline costs would complete the picture on the total costs associated with the CDM and enable the calculation of marginal abatement costs – a more exact measure of the cost per CER.

Compliance cost savings for Annex I Parties are estimated from the difference between the prices of EUAs and CERs. This ignores the effect of CERs on the price of EUAs, which could be a source of much larger savings. Such analyses would require an econometric method to measure cross elasticity and price changes or a computer model of the EU emissions trading system. Similar analyses of the compliance cost savings for Japan and New Zealand would complement the EU ETS estimates.

CERs are accepted for compliance by most existing and proposed emissions trading systems, although often with qualitative or quantitative restrictions. The CERs provide some liquidity and price protection benefits for those emissions trading systems. Since CERs are accepted by many trading systems, they also serve to indirectly link those systems. This may yield cost savings by narrowing the price differences between different trading systems. A better understanding of these benefits would be very useful. Documenting existing and proposed provisions for the use of CERs and experiences with their use to-date is a necessary first step.

Until an “equitable regional distribution” of CDM projects is defined, analyses will be limited to documenting the regional distribution of CDM projects and attempting to understand factors that influence that distribution. Host country emissions, national savings and institutional capacity for the CDM currently appear to be the key factors. More research is needed to better understand these and other key factors relating to regional distribution. This will strengthen the effectiveness of efforts to improve access to the CDM and its co-benefits, especially for countries that can most benefit from them and may have relatively small national emissions and economies.

The additionality of the emission reductions achieved by CDM projects is critical to their environmental integrity. A CDM project can reduce GHG emissions in several ways:

1. Project reductions during its crediting period;[152]
2. Project reductions after the end of the crediting period;[153]
3. Increased adoption of the project's climate friendly technology in the host country due to increased awareness and/or technology transfer; and
4. Less emissions leakage from Parties included in Annex B to the Kyoto Protocol, owing to reduced compliance costs.

The CDM additionality tests focus only on the first category of GHG emission reductions. The emission reductions in the second category can be calculated from available data. While some research is available on the emission reductions in the latter two categories, more research is needed for each category. There is not yet sufficient evidence to conclude that the emission reductions, in the first category, or overall, exceed the CERs issued for CDM projects. Such an analysis would require a global integrated assessment model of world wide economic and emissions activity.

CDM methodologies, due to their large number and extensive use, influence the methodologies for other offset systems. In effect, the CDM is serving as an international quality body for offset methodologies. The role of CDM methodologies relative to other offset methodologies could be documented; different methodologies and their frequency of use for example. That could lead to identification of possible improvements to the CDM methodologies and others. A role for an international quality body might also be identified.

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[152] Huang et al. 2012b empirically investigates the impacts of CDM projects on $CO_2$ emission reductions for 60 CDM host countries from 2005 to 2010 and finds that CDM activity reduces $CO_2$ emissions in CDM host countries. However, they do not compare the host country emission reductions with the emission reductions claimed by the CDM projects to assess whether there is a net reduction in $CO_2$ emissions.

[153] Data for 3,035 registered projects indicate that emission reductions over their operating lives would exceed emission reductions during their crediting periods by 28%. Hydro projects are the largest contributor (40%) to those extra reductions.

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# VIII. ANNEX A

Table A-1. **Definitions of project types applicable for the projects analyzed in this study.**

| Project type | Definition |
|---|---|
| Afforestation and reforestation | According to land use, land-use change and forestry rules |
| Agriculture | Irrigation, alternative fertilizers and rice crop methane avoidance |
| Methane avoidance | Biogas from manure, waste water, industrial solid waste and palm oil solid waste, or methane avoidance by composting or aerobic treatment |
| Biomass energy | New plant using biomass or existing ones changing from fossil fuels to biomass; also biofuels |
| Cement | Projects where lime in the cement is replaced by other materials, or neutralization with lime is avoided |
| $CO_2$ capture | Recovered $CO_2$ from tail gas substituting fossil fuels for production of $CO_2$ |
| Coal bed/mine methane | $CH_4$ is collected from coal mines or coal beds. This includes ventilation air methane (VAM) |
| Energy distribution | Reduction in losses in transmission/distribution of electricity/district heat; country interconnection |
| Energy efficiency households | Energy efficiency improvements in domestic houses and appliances |
| Energy efficiency industry | End-use energy efficiency improvements in industry |
| Energy efficiency own generation | Waste heat or waste gas used for electricity production in industry |
| Energy efficiency service | Energy efficiency improvements in buildings and appliances in public and private service |
| Energy efficiency supply side | More efficient power plants producing electricity and district heat, coal field fire extinguishing |
| Fossil fuel switch | Switch from one fossil fuel to another fossil fuel (including new natural gas power plants) |
| Fugitive | Recovery instead of flaring of $CH_4$ from oil wells, gas pipeline leaks, charcoal production and fires in coal piles |
| Geothermal | Geothermal energy |
| HFCs | HFC-23 destruction |
| Hydro | New hydro power plants |
| Landfill gas | Collection of landfill gas, composting of municipal solid waste, or incinerating of the waste instead of landfilling |
| $N_2O$ | Reduction of $N_2O$ from production of nitric acid, adipic acid and caprolactam |
| PFCs and $SF_6$ | Reduction of emissions of PFCs and $SF_6$ |
| Solar | Solar photovoltaic, solar water heating and solar cooking |
| Tidal | Tidal power |
| Transport | More efficient transport |

## Table A-2. Technology transfer by project type

| Project type | Number of projects | Average projects size (t $CO_2$ e/year) | Technology transfer claims as a percentage of: Number of projects | Technology transfer claims as a percentage of: Annual emission reductions | Percentage of projects where technology transfer could not be determined |
|---|---|---|---|---|---|
| Afforestation/Reforestation | 38 | 39,308 | 41% | 29% | 24% |
| Biomass energy | 422 | 63,949 | 32% | 41% | 30% |
| Cement | 19 | 169,134 | 17% | 16% | 37% |
| $CO_2$ usage | 2 | 11,844 | 100% | 100% | 50% |
| Coal bed/mine methane | 57 | 469,118 | 56% | 70% | 12% |
| Energy efficiency households | 30 | 41,722 | 54% | 71% | 57% |
| Energy efficiency industry | 68 | 26,047 | 74% | 77% | 50% |
| Energy efficiency own generation | 235 | 153,666 | 42% | 64% | 23% |
| Energy efficiency service | 5 | 11,756 | 75% | 94% | 20% |
| Energy efficiency supply side | 36 | 413,726 | 76% | 92% | 42% |
| Energy distribution | 6 | 610,558 | 60% | 39% | 17% |
| Fossil fuel switch | 71 | 499,488 | 85% | 93% | 27% |
| Fugitive | 26 | 611,470 | 63% | 81% | 38% |
| Geothermal | 12 | 265,165 | 88% | 97% | 33% |
| HFCs | 23 | 3,569,649 | 91% | 97% | 0% |
| Hydro | 1128 | 107,656 | 13% | 9% | 16% |
| Landfill gas | 228 | 163,319 | 86% | 89% | 21% |
| Methane avoidance | 436 | 38,223 | 81% | 83% | 18% |
| $N_2O$ | 70 | 713,660 | 100% | 100% | 6% |
| PFCs and $SF_6$ | 12 | 309,602 | 86% | 94% | 42% |
| Solar | 65 | 28,269 | 51% | 38% | 12% |
| Tidal | 1 | 315,440 | 100% | 100% | 0% |
| Transport | 12 | 145,067 | 80% | 93% | 17% |
| Wind | 947 | 103,132 | 29% | 32% | 7% |
| **Total** | **3949** | **147,739** | **39%** | **59%** | **18%** |

## Table A-3. **Diversity of technology supply by project type**

| Project type | Number of projects | Projects with no Technology transfer | Number of projects that claim technology transfer | Number of known technology suppliers | Share of four largest suppliers* | Share of largest supplier* | Largest supplier |
|---|---|---|---|---|---|---|---|
| Afforestation/Reforestation | 38 | 17 | 12 | 7 | 70% | 25% | Norway |
| Biomass energy | 422 | 200 | 94 | 25 | 29% | 23% | Denmark |
| Cement | 19 | 10 | 2 | 2 | | 50% | Japan/Germany |
| $CO_2$ usage | 2 | | 1 | 1 | | 100% | Denmark |
| Coal bed/mine methane | 57 | 22 | 28 | 9 | 79% | 33% | USA |
| Energy efficiency households | 30 | 6 | 7 | 2 | | 94% | Germany |
| Energy efficiency industry | 68 | 9 | 25 | 13 | 58% | 33% | Japan |
| Energy efficiency own generation | 235 | 106 | 76 | 7 | 97% | 59% | Japan |
| Energy efficiency service | 5 | 1 | 3 | 2 | | | |
| Energy efficiency supply side | 36 | 5 | 16 | 12 | 63% | 23% | Vietnam |
| Energy distribution | 6 | 2 | 3 | 2 | | 67% | USA |
| Fossil fuel switch | 71 | 8 | 44 | 12 | 88% | 40% | USA |
| Fugitive | 26 | 6 | 10 | 3 | | 82% | USA |
| Geothermal | 12 | 1 | 7 | 10 | 77% | 35% | USA |
| HFCs | 23 | 2 | 21 | 6 | 81% | 24% | France/Japan/Germany |
| Hydro | 1,128 | 822 | 127 | 23 | 73% | 49% | China |
| Landfill gas | 228 | 25 | 156 | 24 | 49% | 16% | USA |
| Methane avoidance | 436 | 67 | 290 | 26 | 56% | 20% | USA |
| $N_2O$ | 70 | | 66 | 11 | 87% | 41% | Germany |
| PFCs and $SF_6$ | 12 | 1 | 6 | 3 | | 33% | |
| Solar | 65 | 28 | 29 | 9 | 79% | 34% | USA |
| Tidal | 1 | | 1 | 1 | | 100% | Austria |
| Transport | 12 | 2 | 8 | 5 | 88% | 38% | France |
| Wind | 947 | 627 | 250 | 14 | 93% | 41% | Germany |
| **Total** | **3,949** | **1,967** | **1,282** | **44** | **51%** | **19%** | **Germany** |

Note: * as a share of total projects

### Table A-4. **Coefficients of the estimated regression equations (coefficients that are significant at the 0.05 level or more are highlighted)**

| | Single Equation | | | Two Equation Approach | | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **Coefficient[a]** | **Marginal Effect[b]** | **Lag** | **Equation 1 Coefficient[a]** | **Marginal Effect[b]** | **Equation 2 Coefficient** | **Lag** |
| Size | 5.85E-07 | 5.46E-08 | | 1.00E-06 | 1.49E-07 | | |
| Small scale[c] | -1.303 | -0.110 | | -0.836 | -0.164 | | |
| Number | -0.005 | -4.66E-04 | | -0.006 | -0.001 | | |
| Year 2000[c] | | | | 1.104 | 0.240 | | |
| Year 2001[c] | | | | 0.578 | 0.115 | | |
| Year 2002[c] | | | | 0.891 | 0.188 | | |
| Year 2003[c] | 1.700 | 0.282 | | 0.610 | 0.122 | | |
| Year 2004[c] | 2.611 | 0.478 | | 1.380 | 0.303 | | |
| Year 2005[c] | 1.980 | 0.300 | | 0.678 | 0.133 | | |
| Year 2006[c] | 0.604 | 0.066 | | 0.531 | 0.101 | | |
| Year 2008[c] | -0.648 | -0.052 | | -0.754 | -0.113 | | |
| Year 2009[c] | -0.408 | -0.033 | | -1.340 | -0.169 | | |
| Year 2010[c] | | | | -1.231 | -0.153 | | |
| Year 2011[c] | | | | -1.744 | -0.177 | | |
| Argentina[c] | | | | 1.564 | 0.355 | | |
| Brazil[c] | | | | 0.035 | 0.006 | | |
| Chile[c] | | | | 3.424 | 0.678 | | |
| Colombia[c] | | | | 2.185 | 0.495 | | |
| Costa Rica[c] | | | | 2.241 | 0.506 | | |
| Ecuador[c] | | | | 3.497 | 0.683 | | |
| El Salvador[c] | | | | 1.495 | 0.338 | | |
| India[c] | | | | -1.189 | -0.164 | | |
| Indonesia[c] | | | | 4.290 | 0.741 | | |
| Iran[c] | | | | 4.123 | 0.725 | | |
| Korea (South)[c] | | | | 2.693 | 0.587 | | |
| Malaysia[c] | | | | 3.482 | 0.687 | | |
| Mexico[c] | | | | 3.936 | 0.730 | | |
| Nigeria[c] | | | | 3.936 | 0.713 | | |
| Peru[c] | | | | 2.829 | 0.607 | | |
| Philippines[c] | | | | 0.712 | 0.145 | | |

| | Single Equation | | | Two Equation Approach | | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **Coefficient[a]** | **Marginal Effect[b]** | **Lag** | **Equation 1 Coefficient[a]** | **Marginal Effect[b]** | **Equation 2 Coefficient** | **Lag** |
| Senegal[c] | | | | 3.506 | 0.682 | | |
| South Africa[c] | | | | 1.965 | 0.448 | | |
| Sri Lanka[c] | | | | 5.430 | 0.763 | | |
| Uganda[c] | | | | 6.431 | 0.774 | | |
| Uruguay[c] | | | | 4.347 | 0.735 | | |
| Viet Nam[c] | | | | 6.463 | 0.798 | | |
| Afforestation[c] | | | | -1.890 | -0.184 | | |
| Biomass energy[c] | -1.466 | -0.084 | | 0.294 | -0.054 | | |
| Cement[c] | -0.441 | -0.035 | | -0.154 | -0.026 | | |
| Coal bed/mine methane[c] | 0.512 | 0.058 | | 1.727 | 0.393 | | |
| Energy efficiency households[c] | | | | 3.262 | 0.660 | | |
| Energy efficiency industry[c] | | | | 3.586 | 0.692 | | |
| Energy efficiency own generation[c] | | | | 1.635 | 0.365 | | |
| Energy efficiency supply side[c] | 4.008 | 0.760 | | 2.207 | 0.500 | | |
| Energy distribution[c] | 1.645 | 0.271 | | 1.139 | 0.250 | | |
| Fossil fuel switch[c] | | | | 2.124 | 0.482 | | |
| Fugitive[c] | | | | -5.367 | -0.224 | | |
| Geothermal[c] | -2.638 | -0.096 | | -1.533 | -0.165 | | |
| HFCs[c] | 1.849 | 0.318 | | 3.327 | 0.668 | | |
| Landfill gas[c] | 1.662 | 0.266 | | 3.106 | 0.648 | | |
| Methane avoidance[c] | 1.452 | 0.212 | | 1.873 | 0.416 | | |
| PFCs and $SF_6$[c] | 1.847 | 0.320 | | 2.449 | 0.546 | | |
| Solar[c] | -1.904 | -0.088 | | 1.623 | 0.368 | | |
| Transport[c] | | | | 2.895 | 0.616 | | |
| Wind[c] | 4.031 | 0.619 | | 3.340 | 0.657 | | |
| Population | -0.446 | -0.042 | 1 | | | -0.050 | 1 |
| Per capita GDP | 1.16E-05 | 1.08E-06 | 1 | | | -3.01E-05 | 1 |
| FDI | 0.182 | -0.017 | 1 | | | -0.046 | 2 |
| Capital formation | -0.263 | -0.025 | 1 | | | 3.62E-04 | 3 |
| Imports | 0.103 | 0.010 | 3 | | | -0.002 | 3 |

| | Single Equation | | | Two Equation Approach | | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **Coefficient**[a] | **Marginal Effect**[b] | **Lag** | **Equation 1 Coefficient**[a] | **Marginal Effect**[b] | **Equation 2 Coefficient** | **Lag** |
| Exports | 0.009 | -0.001 | 3 | | | -0.010 | 1 |
| Tariff | -0.159 | -0.015 | 0 | | | -0.004 | 3 |
| ODA | 0.454 | -0.042 | 1 | | | 0.047 | 1 |
| Renewable | -0.036 | -0.003 | | | | | |
| Knowledge | 9.44E-06 | 8.81E-07 | | | | -8.64E-07 | |
| Technology | -0.004 | -3.55E-04 | 1 | | | -6.64E-04 | 1 |
| Transfer | 0.004 | 3.78E-04 | 2 | | | 4.33E-04 | 1 |
| Potential | -0.005 | -4.47E-04 | | | | -0.003 | |
| Cost | 0.017 | 0.002 | | | | 8.56E--04 | |
| Constant | 14.551 | | | -1.468 | | 1.301 | |
| Observations | 1,839 | | | 2,964 | | 168 | |
| Pearson's Chi$^{2}$[d] | 1,220 | | | 1,870 | | 10.9[e] | |
| Probability > Chi$^{2}$[d] | 0.00 | | | 0.00 | | 0.00[e] | |
| Pseudo R$^{2}$[f] | 0.569 | | | 0.494 | | 0.435 | |
| Correctly classified[g] | 88.7% | | | 85.1% | | | |

Notes:

a. Binomial logit regression. The coefficients describe the effects of the independent variables on the predicted logarithmic odds of technology transfers.

b. The marginal effect is the effect of a one-unit change in the variable on the predicted probability of technology transfer. This is the same as the coefficient estimated using the ordinary least squares method. Thus the marginal effects for the single equation can be compared with the coefficient for equation 2. For example, the marginal effect of Exports is -.014. This implies that if the host country's exports as a percentage of GDP rise 1 percentage point, the model predicts a drop in probability of technology transfer of 1.4 percentage points, other things equal. The marginal effect of Size is 1.59E-07, which implies that if a project's estimated annual emission reductions increase by 1 t CO$_2$ e/year, the model predicts an increase in probability of technology transfer of 1.59E-07, other things equal. In the case of a dummy variable, the marginal effect is the effect of the presence of the characteristic on the predicted probability of technology transfer. For example, the single equation predicts that the probability of technology transfer is 27.9% lower for a hydro project, other things equal.

c. A dummy variable that takes on the values 1 and 0; 1 means something is true. Dummy variables are also called indicator variables.

d. The value of the Pearson Chi$^2$ is used to test the null hypothesis that the coefficients of all of the variables are equal to zero. The probability of a Chi$^2$ value greater than the value calculated for each of the equations is less than 0.0000, indicating that at least some of the variables are statistically significant. That is confirmed by tests for the individual coefficients. The shaded values in the table indicate coefficients statistically significant at the 5% confidence level.

e. In the case of ordinary least squares estimation, the F test is used to test the null hypothesis that the coefficients of all of the variables are equal to zero. The value of F (14, 349) indicates that at least some of the variables are statistically significant, which is confirmed by tests for the individual coefficients.

f. The pseudo R$^2$ is an indicator of the explanatory power of the equation. A value of 0 indicates no explanatory power while a perfect explanation would have an R$^2$ = 1.

g. The percentage of observations correctly classified is another indicator of the explanatory power for the binomial logit equations. If the equation predicts a probability of technology transfer greater than 0.5 for a project, given its characteristics, it is correctly classified if technology transfer was claimed and incorrectly classified if no technology transfer was claimed. Similarly, if the predicted probability is less than 0.5, it is correctly classified if no technology transfer was claimed and incorrectly classified if technology transfer was claimed. Since the dependent variable for Equation 2 can have any value between 0 and 1 inclusive, the correctly classified calculation cannot be applied to that equation.

Table A-5. **Capital investment by project types (USD million)**

| Project type | Registered and operating | Registered implementation unknown | Expected to be registered | Total |
|---|---|---|---|---|
| Afforestation/reforestation | 115 | 156 | 12 | 282 |
| Biomass energy | 3,435 | 2,716 | 708 | 6,860 |
| Cement | 158 | 77 | 6 | 240 |
| $CO_2$ usage | 23 | 9 | 10 | 42 |
| Coal bed/mine methane | 802 | 277 | 248 | 1,326 |
| Energy efficiency households | 37 | 17 | 6 | 60 |
| Energy efficiency industry | 797 | 242 | 370 | 1,409 |
| Energy efficiency own generation | 4,375 | 1,757 | 777 | 6,908 |
| Energy efficiency service | 28 | 20 | 1 | 50 |
| Energy efficiency supply side | 1,782 | 15,044 | 4,491 | 21,316 |
| Energy distribution | 821 | 1 | 270 | 1,091 |
| Fossil fuel switch | 9,585 | 1,133 | 1,462 | 12,181 |
| Fugitive | 1,638 | 268 | 107 | 2,013 |
| Geothermal | 1,324 | 142 | 1,447 | 2,913 |
| HFCs | 59 | 6 | - | 64 |
| Hydro | 23,252 | 21,805 | 8,445 | 53,502 |
| Landfill gas | 1,411 | 1,055 | 737 | 3,204 |
| Methane avoidance | 556 | 506 | 185 | 1,247 |
| $N_2O$ | 380 | 62 | 84 | 526 |
| PFCs and $SF_6$ | 106 | 18 | - | 124 |
| Solar | 962 | 4,178 | 820 | 5,961 |
| Tidal | 384 | - | - | 384 |
| Transport | 2,206 | 4,999 | 2,941 | 10,146 |
| Wind | 37,981 | 33,131 | 12,406 | 83,518 |
| **Total** | **92,218** | **87,618** | **35,532** | **215,369** |

## Table A-6. Estimated capital investment for operating, registered and projects undergoing registering by host country (USD million)

| Country | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Number of operating projects | Number of registered projects (implementation unknown) | Number of registeering options | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Albania | - | - | - | - | 5 | - | - | - | - | 216 | - | - | 937 | - | - | 942 | 216 | 1,158 |
| Argentina | 1 | 20 | - | - | 158 | 13 | 146 | 19 | 108 | 10 | 5 | 7 | - | - | 213 | 244 | 29 | 486 |
| Armenia | - | - | - | - | - | 3 | 14 | - | 23 | - | - | - | - | - | 16 | 6 | 18 | 40 |
| Azerbaijan | - | - | - | - | - | 398 | 60 | 133 | - | 89 | - | - | - | - | - | 89 | 591 | 680 |
| Bahamas | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | 2 | 2 |
| Bangladesh | - | - | - | - | - | - | 34 | - | - | - | 2 | - | - | - | 24 | 9 | 2 | 36 |
| Bhutan | - | - | - | - | 0 | - | 184 | - | - | - | - | - | - | - | 0 | 184 | - | 184 |
| Bolivia | 60 | - | - | - | - | 3 | - | - | 47 | - | - | - | - | - | 60 | 50 | - | 110 |
| Bosnia and Herzegovina | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | 3 | 3 |
| Brazil | 39 | 127 | 660 | 354 | 506 | 229 | 661 | 715 | 397 | 578 | 85 | 60 | 23 | - | 2,572 | 1,191 | 671 | 4,434 |
| Cambodia | - | - | - | - | - | - | 16 | 13 | 4 | - | 3 | - | - | - | 13 | 23 | - | 36 |
| Cameroon | - | - | - | - | - | - | - | - | - | 6 | 2 | - | - | - | 6 | 2 | - | 8 |
| Chile | 4 | 33 | 59 | 64 | 170 | 7 | 326 | 472 | 411 | 90 | 55 | 46 | - | - | 1,171 | 317 | 248 | 1,736 |
| China | - | - | 87 | 1,890 | 4,243 | 13,870 | 16,033 | 19,100 | 19,869 | 21,432 | 19,608 | 11,222 | 392 | 9 | 63,543 | 45,003 | 19,209 | 127,755 |
| Colombia | 16 | - | 2,127 | 51 | 486 | 446 | 23 | 12 | 275 | 103 | 11 | 6 | - | 45 | 2,248 | 1,223 | 131 | 3,601 |
| Congo DR | - | - | - | - | - | - | - | - | 12 | - | - | 3 | - | - | - | 16 | - | 16 |
| Costa Rica | 27 | - | - | 12 | - | - | 24 | 99 | 1 | - | 40 | - | - | - | 163 | 2 | 38 | 203 |
| Côte d`Ivoire | - | - | - | - | - | - | - | - | 6 | 13 | - | 6 | - | - | - | 24 | - | 24 |
| Cuba | - | - | - | 88 | - | - | - | 4 | - | - | - | - | - | - | 92 | - | - | 92 |
| Cyprus | - | - | - | 16 | - | - | 13 | 45 | 374 | - | - | 82 | - | - | 378 | 151 | - | 530 |
| Dominican Republic | - | - | - | - | - | - | - | - | 4 | - | 185 | - | - | - | 4 | 178 | 7 | 190 |
| Ecuador | 1 | - | - | 2 | 21 | 51 | 68 | 111 | 470 | 5 | 15 | - | - | - | 161 | 109 | 473 | 744 |
| Egypt | - | - | - | 28 | 27 | 86 | 263 | 152 | 13 | 37 | - | - | - | - | 339 | 254 | 13 | 606 |
| El Salvador | - | - | 12 | - | - | 28 | 119 | 23 | 163 | - | - | - | - | - | 182 | 163 | - | 345 |
| Ethiopia | - | - | - | - | - | - | 7 | - | - | - | - | - | - | - | 7 | - | - | 7 |
| Fiji | - | - | - | - | 15 | - | - | - | - | 2 | - | - | - | - | 15 | 2 | - | 17 |
| Georgia | - | - | - | - | - | - | - | - | 33 | - | 14 | - | - | - | 28 | 5 | 14 | 47 |
| Guatemala | 57 | - | 22 | 112 | - | 6 | 148 | - | 256 | - | - | - | - | - | 339 | 262 | - | 601 |

| Country | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Number of operating projects | Number of registered projects (implementation unknown) | Number of registeering options | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guyana | - | - | - | - | - | 32 | - | - | - | - | - | - | - | - | - | 32 | - | 32 |
| Honduras | - | - | 5 | 34 | 15 | 16 | 22 | 19 | 14 | - | 202 | - | - | - | 98 | 58 | 172 | 328 |
| India | 452 | 561 | 817 | 1,231 | 1,800 | 4,582 | 2,298 | 5,210 | 13,766 | 5,291 | 814 | 303 | 7 | - | 10,728 | 21,913 | 4,490 | 37,131 |
| Indonesia | - | - | - | - | 105 | 77 | 940 | 409 | 139 | 364 | 167 | 1,460 | - | - | 975 | 833 | 1,853 | 3,661 |
| Iran | - | - | - | - | - | - | 118 | 46 | - | - | - | - | - | - | 119 | 44 | - | 164 |
| Israel | - | - | - | 1 | - | 18 | 21 | 54 | 3 | 37 | 911 | 99 | 145 | - | 50 | 1,183 | 57 | 1,290 |
| Jamaica | - | - | - | - | 20 | - | - | - | - | 48 | - | - | - | - | 20 | 48 | - | 68 |
| Jordan | - | - | 25 | - | 176 | - | - | - | - | - | - | - | 28 | - | 25 | 204 | - | 229 |
| Kenya | - | - | - | - | - | - | 20 | 204 | 2 | - | 2 | 655 | - | - | 110 | 773 | - | 883 |
| Democratic People's Republic of Korea | - | - | - | - | - | - | - | - | - | - | 13 | 5 | - | - | - | - | 18 | 18 |
| Republic of Korea | - | - | - | 1 | 384 | 297 | 353 | 1,034 | 327 | 145 | 54 | 15 | - | - | 2,037 | 562 | 10 | 2,610 |
| Lao PDR | - | - | - | - | - | 118 | 265 | 118 | - | - | - | - | - | - | 32 | 233 | 236 | 501 |
| Lesotho | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 |
| Liberia | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | 1 |
| Macedonia | - | - | - | - | - | - | - | 19 | - | - | - | - | - | - | - | 19 | - | 19 |
| Madagascar | - | - | - | - | - | - | - | 11 | - | - | - | - | - | - | 5 | 6 | - | 11 |
| Malaysia | 2 | - | 35 | 1 | 14 | 15 | 151 | 349 | 191 | 36 | 10 | 11 | - | - | 416 | 326 | 74 | 817 |
| Mali | - | - | - | - | - | - | - | - | - | 110 | - | - | - | - | - | 110 | - | 110 |
| Mauritius | - | - | - | - | - | - | - | 4 | - | - | - | - | 24 | - | - | 28 | - | 28 |
| Mexico | - | - | 13 | - | 110 | 140 | 431 | 902 | 4,838 | 401 | 620 | 443 | 12 | - | 1,559 | 2,791 | 3,559 | 7,909 |
| Moldova | - | - | 19 | - | - | - | 28 | - | 43 | - | - | 80 | - | - | 47 | 19 | 104 | 170 |
| Mongolia | - | - | - | - | 65 | - | 1 | - | - | - | - | 132 | - | - | 65 | 133 | - | 198 |
| Morocco | - | - | - | - | 110 | 128 | 8 | 254 | 48 | - | 270 | - | - | - | 244 | 518 | 54 | 817 |
| Nepal | - | - | - | 7 | 7 | 8 | 8 | 59 | - | - | 0 | - | - | - | 14 | 76 | - | 90 |
| Nicaragua | - | - | 31 | 2 | 177 | - | - | 86 | 3 | 44 | - | - | - | - | 339 | 3 | - | 342 |
| Nigeria | - | - | - | - | - | 476 | - | 302 | 2 | - | 404 | - | - | - | 703 | 107 | 374 | 1,184 |
| Pakistan | - | - | - | - | - | 24 | 20 | 357 | 30 | - | 29 | - | - | - | 120 | 243 | 96 | 459 |
| Panama | - | 15 | - | - | - | 15 | 136 | - | 21 | 93 | - | 191 | - | - | 53 | 223 | 194 | 470 |
| Papua New Guinea | - | - | - | - | 176 | - | - | - | 19 | - | - | 5 | - | - | 176 | 24 | - | 200 |

| Country | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Number of operating projects | Number of registered projects (implementation unknown) | Number of registeering options | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paraguay | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | 2 | - | 2 |
| Peru | - | - | 17 | 3 | 163 | 13 | 359 | 207 | 16 | 382 | 220 | - | 137 | - | 364 | 952 | 201 | 1,517 |
| Philippines | 0 | - | 1 | - | 52 | 98 | 104 | 132 | 362 | 21 | - | - | 14 | - | 239 | 530 | 14 | 783 |
| Qatar | - | - | - | - | 260 | - | - | - | - | - | - | - | - | - | 260 | - | - | 260 |
| Rwanda | - | - | - | - | - | - | - | 1 | - | 7 | - | 8 | - | - | - | 17 | - | 17 |
| Saudi Arabia | - | - | - | - | - | - | - | - | 5 | - | - | - | - | - | - | - | 5 | 5 |
| Senegal | - | - | - | - | - | - | - | 30 | 16 | - | - | 8 | 197 | - | - | 243 | 8 | 252 |
| Serbia | - | - | - | - | - | - | - | - | - | - | - | - | 1,001 | - | - | 1,001 | - | 1,001 |
| Singapore | - | - | - | - | - | - | 6 | 4 | 22 | - | - | - | - | - | 26 | - | 6 | 32 |
| South Africa | - | - | - | - | 21 | 1 | 44 | 42 | 3 | - | 10 | 31 | - | - | 113 | 6 | 32 | 151 |
| Sri Lanka | - | 2 | - | 24 | 15 | 28 | - | - | 8 | - | 14 | - | - | - | 77 | - | 14 | 91 |
| Syria | - | - | - | - | - | - | - | - | 4 | 5 | - | 5 | - | - | - | 14 | - | 14 |
| Tanzania | - | - | - | - | - | - | - | 8 | - | - | - | - | - | - | 8 | - | - | 8 |
| Thailand | - | - | 85 | 28 | 87 | 72 | 41 | 331 | 47 | 103 | 234 | 23 | - | - | 368 | 384 | 298 | 1,049 |
| Tunisia | - | - | - | - | - | - | - | 11 | 231 | - | - | - | - | - | 11 | - | 231 | 242 |
| Uganda | - | - | - | 15 | - | - | 7 | 800 | 24 | 10 | - | - | 1 | - | 41 | 807 | 8 | 857 |
| United Arab Emirates | - | - | - | - | - | - | - | 37 | 372 | - | - | - | 2 | - | 75 | 333 | 2 | 410 |
| Uruguay | 2 | - | - | - | - | 19 | - | 50 | 7 | 2 | - | - | - | - | 8 | 53 | 19 | 80 |
| Uzbekistan | - | - | - | - | - | - | - | 12 | 41 | 64 | 252 | 1 | - | - | 229 | 142 | - | 371 |
| Vietnam | - | 180 | - | - | - | 28 | 296 | 1,179 | 704 | 788 | 901 | 640 | 79 | - | 886 | 2,173 | 1,736 | 4,795 |
| Zambia | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | 4 | - | - | 4 |
| **Total** | **662** | **937** | **4,013** | **3,965** | **9,386** | **21,344** | **23,814** | **33,181** | **43,780** | **30,533** | **25,151** | **15,550** | **2,998** | **54** | **92,218** | **87,618** | **35,532** | **215,369** |

## Table A-7. **Estimated revenue from the sale of CERs at primary market prices (USD million)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | Total |
|---|---|---|---|---|---|---|
| Argentina | 1 | 6 | 25 | 21 | 40 | **93** |
| Armenia | 0 | 0 | 0 | 0 | 0 | **0** |
| Bhutan | 0 | 0 | 0 | 0 | 0 | **0** |
| Bolivia | 0 | 7 | 1 | 0 | 1 | **10** |
| Brazil | 23 | 402 | 97 | 95 | 151 | **769** |
| Cambodia | 0 | 0 | 0 | 0 | 0 | **0** |
| Chile | 14 | 17 | 14 | 11 | 33 | **89** |
| China | 95 | 1,230 | 1,063 | 869 | 2,213 | **5,470** |
| Colombia | 0 | 3 | 4 | 2 | 8 | **18** |
| Costa Rica | 0 | 0 | 0 | 0 | 3 | **3** |
| Cuba | 0 | 0 | 0 | 2 | 0 | **2** |
| Dominican Republic | 0 | 0 | 0 | 0 | 0 | **0** |
| Ecuador | 0 | 7 | 1 | 3 | 3 | **14** |
| Egypt | 0 | 33 | 19 | 13 | 24 | **89** |
| El Salvador | 0 | 0 | 5 | 0 | 4 | **9** |
| Fiji | 0 | 0 | 0 | 0 | 0 | **0** |
| Georgia | 0 | 0 | 0 | 0 | 3 | **3** |
| Guatemala | 0 | 4 | 6 | 1 | 2 | **12** |
| Honduras | 0 | 1 | 2 | 2 | 2 | **7** |
| India | 5 | 822 | 227 | 106 | 396 | **1,555** |
| Indonesia | 0 | 2 | 3 | 0 | 28 | **33** |
| Israel | 0 | 0 | 3 | 3 | 6 | **13** |
| Jamaica | 0 | 2 | 1 | 0 | 0 | **3** |
| Jordan | 0 | 0 | 3 | 7 | 2 | **11** |
| Republic of Korea | 26 | 479 | 154 | 151 | 190 | **999** |
| Laos | 0 | 0 | 0 | 0 | 0 | **0** |
| Malaysia | 0 | 9 | 1 | 1 | 9 | **20** |
| Mexico | 9 | 69 | 10 | 13 | 67 | **168** |
| Mongolia | 0 | 0 | 0 | 0 | 0 | **0** |
| Morocco | 0 | 0 | 0 | 1 | 3 | **4** |
| Nepal | 0 | 0 | 0 | 0 | 1 | **1** |

| | 2007 | 2008 | 2009 | 2010 | 2011 | Total |
|---|---|---|---|---|---|---|
| Nicaragua | 2 | 3 | 2 | 0 | 0 | **8** |
| Nigeria | 0 | 0 | 0 | 0 | 3 | **3** |
| Pakistan | 0 | 5 | 18 | 3 | 13 | **38** |
| Panama | 0 | 0 | 0 | 0 | 1 | **1** |
| Papua New Guinea | 0 | 3 | 0 | 0 | 0 | **3** |
| Peru | 0 | 2 | 1 | 3 | 8 | **13** |
| Philippines | 0 | 0 | 1 | 1 | 2 | **4** |
| South Africa | 0 | 4 | 7 | 9 | 4 | **24** |
| Sri Lanka | 0 | 3 | 0 | 0 | 0 | **3** |
| Tanzania | 0 | 0 | 0 | 0 | 0 | **1** |
| Thailand | 0 | 2 | 9 | 0 | 1 | **11** |
| Uganda | 0 | 0 | 0 | 0 | 0 | **0** |
| United Arab Emirates | 0 | 0 | 0 | 0 | 1 | **1** |
| Uruguay | 0 | 0 | 0 | 0 | 0 | **0** |
| Uzbekistan | 0 | 0 | 0 | 0 | 0 | **0** |
| Vietnam | 0 | 38 | 0 | 10 | 26 | **74** |
| Zambia | 0 | 0 | 0 | 0 | 0 | **0** |
| **Total** | **177** | **3,154** | **1,676** | **1,325** | **3,251** | **9,583** |

Table A-8. **Estimated revenue from the sale of CERs at secondary market prices (USD million)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | Total |
|---|---:|---:|---:|---:|---:|---:|
| Argentina | 2 | 9 | 33 | 29 | 53 | **126** |
| Armenia | 0 | 0 | 0 | 0 | 0 | **0** |
| Bhutan | 0 | 0 | 0 | 0 | 0 | **0** |
| Bolivia | 0 | 11 | 2 | 0 | 1 | **14** |
| Brazil | 39 | 611 | 127 | 132 | 201 | **1,111** |
| Cambodia | 0 | 0 | 0 | 0 | 0 | **0** |
| Chile | 23 | 26 | 18 | 15 | 44 | **127** |
| China | 161 | 1,870 | 1,391 | 1,207 | 2,943 | **7,572** |
| Colombia | 0 | 5 | 6 | 3 | 11 | **24** |
| Costa Rica | 0 | 0 | 0 | 0 | 4 | **5** |
| Cuba | 0 | 0 | 0 | 3 | 1 | **3** |
| Dominican Republic | 0 | 0 | 0 | 0 | 0 | **0** |
| Ecuador | 0 | 10 | 1 | 4 | 5 | **21** |
| Egypt | 0 | 51 | 24 | 18 | 32 | **125** |
| El Salvador | 0 | 0 | 7 | 0 | 5 | **12** |
| Fiji | 0 | 0 | 0 | 0 | 0 | **0** |
| Georgia | 0 | 0 | 0 | 0 | 4 | **4** |
| Guatemala | 0 | 6 | 7 | 1 | 3 | **17** |
| Honduras | 0 | 1 | 2 | 2 | 3 | **9** |
| India | 9 | 1,249 | 297 | 147 | 526 | **2,228** |
| Indonesia | 0 | 3 | 3 | 0 | 38 | **44** |
| Israel | 0 | 1 | 4 | 5 | 8 | **17** |
| Jamaica | 0 | 3 | 1 | 1 | 0 | **4** |
| Jordan | 0 | 0 | 4 | 9 | 3 | **16** |
| Republic of Korea | 44 | 729 | 201 | 209 | 252 | **1,435** |
| Lao People’s Democratic Republic | 0 | 0 | 0 | 0 | 0 | **0** |
| Malaysia | 0 | 14 | 1 | 1 | 13 | **29** |
| Mexico | 15 | 105 | 13 | 18 | 90 | **241** |
| Mongolia | 0 | 0 | 0 | 0 | 0 | **0** |
| Morocco | 0 | 1 | 0 | 1 | 4 | **5** |
| Nepal | 0 | 0 | 0 | 0 | 1 | **1** |

| | 2007 | 2008 | 2009 | 2010 | 2011 | Total |
|---|---|---|---|---|---|---|
| Nicaragua | 4 | 4 | 3 | 1 | 0 | **12** |
| Nigeria | 0 | 0 | 0 | 0 | 4 | **4** |
| Pakistan | 0 | 7 | 23 | 4 | 17 | **51** |
| Panama | 0 | 0 | 0 | 0 | 2 | **2** |
| Papua New Guinea | 0 | 5 | 0 | 0 | 0 | **5** |
| Peru | 0 | 2 | 1 | 4 | 10 | **17** |
| Philippines | 0 | 0 | 1 | 1 | 3 | **5** |
| South Africa | 0 | 6 | 9 | 12 | 6 | **33** |
| SriLanka | 0 | 4 | 0 | 0 | 0 | **5** |
| Tanzania | 0 | 0 | 0 | 0 | 1 | **1** |
| Thailand | 0 | 2 | 12 | 0 | 1 | **15** |
| Uganda | 0 | 0 | 0 | 0 | 0 | **0** |
| United Arab Emirates | 0 | 0 | 0 | 0 | 1 | **1** |
| Uruguay | 0 | 0 | 0 | 0 | 1 | **1** |
| Uzbekistan | 0 | 0 | 0 | 0 | 0 | **0** |
| VietNam | 0 | 58 | 0 | 14 | 34 | **106** |
| Zambia | 0 | 0 | 0 | 0 | 0 | **0** |
| **Total** | **298** | **4,795** | **2,192** | **1,841** | **4,324** | **13,451** |

# IX. ANNEX B

## 9.1. METHODOLOGY AND DATA SOURCES FOR ESTIMATION OF TOTAL INVESTMENT IN CDM PROJECTS

The PDDs for many CDM projects include financial information[154] relating to the proposed project using a set of tools offered by the CDM Executive Board to demonstrate additionality[155]. Approximately 60 per cent of CDM projects include the capital investment as part of their investment or barrier analysis using these tools. In these cases the expected capital investment is reviewed by a DOE during the validation process. However, information on how these estimates correspond to the actual capital investment is not available.

To obtain an estimate of the total investment in CDM projects, the capital investment from PDDs that provide this information are extrapolated to cover those missing. The estimated investment per tonne of annual $CO_2e$ reduced (USD/t $CO_2e$) is used for the extrapolation.[156] The estimated investment per tonne of annual $CO_2e$ reduced differs significantly by project type and subtype as shown in Figure 10. Hence the extrapolation applies the project type and subtype averages to the projects that do not include an investment analysis to estimate the total investment.

The estimated capital investment has been compiled or estimated for 4,832 projects registered or undergoing registration as of June 2012. The capital investment was available in the PDDs for 2,860 of those projects and totalled USD 147.7 billion. When the capital investment for the other 1,972 projects is extrapolated, the total investment in CDM projects amounts to USD 215.4 billion. Of that total, the investment in operating projects is USD 92.2 billion, USD 87.6 billion for other registered projects and USD 35.5 billion for projects not yet registered.

## 9.2. METHODOLOGY AND DATA SOURCES FOR COMPARISON OF CDM AND ANNEX I RENEWABLE ENERGY PROJECTS

Bloomberg New Energy Finance (BNEF) records data on capital investment, project location and sources of finance for renewable energy projects. Data are collected for non-CDM projects in Annex I countries and CDM projects, which are drawn from UNFCCC sources via UNEP Risø and IGES. The BNEF database is compiled from public information, so coverage is not complete; however the number of missing projects in Annex I countries is believed to be low. Coverage of non-CDM non-Annex I country projects is poor, as information for these projects is generally much less available in the public domain.

The number of projects with capital investment information is shown in Table B-1.

The BNEF database includes only renewable energy projects, so many CDM project types are excluded.[157] Comparison of CDM with similar types of Annex I projects is possible only for geothermal, hydro, solar and wind projects. The number of tidal projects is too small to permit meaningful comparisons and landfill gas and methane avoidance projects are not recorded by BNEF.

Information on project location and sources of finance in the BNEF database is used to classify projects as being domestic or foreign financed. A project is domestically financed if the only source of project finance is the host country. All other projects involve some foreign finance, but these projects usually have some domestic finance.

[154] The information captured from PDDs and used in this study included: capital investment, average annual operational costs, average annual income (non-CER sources), expected operating lifetime, discount rates etc.

[155] Available at: <https://cdm.unfccc.int/Reference/tools/index.html>.

[156] The metric is expressed in USD/t $CO_2e$. This should not be confused with project mitigation costs, which are expressed in similar units, but calculated differently.

[157] The following project types are not recorded by BNEF: Afforestation/reforestation, cement, $CO_2$ usage, coal bed/mine methane, energy efficiency households, energy efficiency industry, energy efficiency own generation, energy efficiency service, energy efficiency supply side, energy distribution, fossil fuel switch, fugitive, HFCs, $N_2O$, PFCs and $SF_6$ and transport.

Table B-1. **Number of projects with capital investment used in the analysis**

| | CDM projects | Non-CDM projects |
|---|---:|---:|
| **Geothermal** | | |
| Conventional | 26 | 66 |
| **Hydro** | | |
| Existing dam | 122 | 11 |
| New dam | 540 | 55 |
| Run of river | 1,654 | 96 |
| **Solar** | | |
| Solar PV | 171 | 895 |
| Solar thermal power | 14 | 74 |
| **Tidal** | | |
| Tidal | 2 | 14 |
| **Wind** | | |
| Onshore | 2,281 | 1,755 |
| **Total** | **4,810** | **2,966** |

## 9.3. METHODOLOGY AND DATA SOURCES FOR CALCULATION OF MITIGATION COSTS FOR CDM PROJECTS

From information contained in PDDs, it is possible to estimate a project's mitigation costs over its lifetime. The mitigation cost is the total cost of the project, including initial outlay of capital, the annual operational expenditure and revenues per CER expected for each project. As shown in equation 1 below, project mitigation cost is defined as the net present value[158] of a project´s annual operations costs less its non-CDM related revenues (e.g. income from electricity sales for wind projects), plus the capital expenditures, all divided by the amount of GHG emission reductions it expects to achieve over its crediting period.[159]

$$C(CDM)_i = \frac{\sum_{t=1}^{cp} \frac{(C_t - R_t)}{(1+r)^t} + I_0}{\sum_{t=1}^{cp} A_t} \qquad \textit{Equation 1}$$

Where:

- *C(CDM)*$_i$ is the mitigation cost of project *i* (in USD /t $CO_2$e) ;
- *t* denotes a given year during the project crediting period;
- *cp* is the length of its crediting period(s) (up to 10 or 21 years);
- $C_t$ is the operating cost in year *t* (in USD);
- $R_t$ is the non-CER revenue in year *t* (in USD);
- $I_0$ is the initial investment (in USD);
- $A_t$ is the abatement (expected emission reduction) achieved by the project in year *t* (in t $CO_2$e);
- *r* is the discount rate (expressed as a decimal; 1% = 0.01).

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[158] As interest rates are generally positive, the net present value is the standard method used in order to discount future costs and benefits to current values.

[159] Castro, 2010, p. 12.

All costs are expressed in USD, calculated using the current interbank exchange rate on the date the project started operation or was submitted for validation. The discount rate is the rate used in the PDD to demonstrate additionality; it is typically expressed as a benchmark rate or hurdle rate. Where a discount rate is not included in the PDD, a country average is applied. Castro (2010) uses a median discount rate by country to normalize abatement costs, as the rate can vary significantly from one project to another within a single host country. However, this study did not find this to be the case.[160]

The crediting period rather than the operational lifetime of the project is used for the calculation since the CDM crediting period most likely informed the investment decision by the project developer. More than 60 per cent of all CDM projects choose a renewable seven-year crediting period for a maximum of 21 years and the remainder choose a single crediting period, up to 10 years. Some projects report a lifetime equal to the crediting period, while others, especially hydro projects, typically have a much longer operational lifetime.

Most PDDs that include an investment analysis provide sufficient information to calculate the mitigation cost per tonne of $CO_2$e emissions reduced. The analysis of mitigation costs reported here uses data for 2,336 projects registered or undergoing registration as of June 2012.

## 9.4. METHODOLOGY TO DETERMINE THE RELATIONSHIP BETWEEN OPERATING CDM PROJECTS IN A COUNTRY AND COUNTRY CHARACTERISTICS

It is clear from this report that most of the investment in CDM projects originates in the host country, so its characteristics are crucial determinants of CDM activity. The relationship between the number operating CDM projects in a country as a measure of regional distribution and some of the more important country characteristics suggested by the literature[161] - national GHG emissions, population, GDP, gross national savings was analysed.

The assessment relied on simple univariate regression analyses where the dependent variable – the number operating CDM projects in a host country is related to selected country characteristics. Although the number of operating projects is a smaller dataset than all registered projects in a host country, it is more germane as the project investment is known to have taken place[162].

As a strong correlation was observed between some country characteristics, the dependant variable was regressed against one country characteristic variable at a time. For instance, a country's national GHG emissions are inherently related to its GDP, which is related to its national GHG emissions and so on.

After each regression model was fitted, a standard test of "goodness of fit" of the resulting model was performed. The goodness of fit describes how close the dependent variable – the number operating CDM projects in a host country is related to each of the independent variables, such that a perfect fit (a perfect relationship) is shown as 100 per cent. Table B-2 presents the results of goodness of fit when the number of operating CDM projects is regressed against national GHG emissions, population, GDP, and gross savings independently (bottom row)[163]. Table B-2 also shows the relationship between individual pairs of country characteristics. For instance, national GHG emissions and gross savings are strongly related to the number of operating CDM projects as indicated by the 95% and 93% fits respectively. However, national GHG emissions and gross savings are also strongly related to each other with a 98% fit. Due to the interrelationship between the independent variables, it is difficult to pinpoint which one is influencing the country's number of CDM projects. More work is needed to isolate the country factors that influence the regional distribution of CDM projects, and to determine whether the relationship is causal or incidental.

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[160] Mitigation costs were calculated using both a country standard discount rate and the discount rates from individual PDDs and no significant differences were found.

[161] See Section 5.

[162] 2,349 operating CDM projects as of June 2012 out of the 3,949 registered or registering projects. Regression performed on all 3,949 projects yielded similar results

[163] Other independent variables tested such as the investment climate indexes were not significance compared to national GHG emissions, population, GDP, and gross savings.

## Table B-2. **Relationship (goodness of fit) between number of projects in a country and selected country characteristics**

| | National GHG emissions | Population | GDP | Gross savings |
|---|---|---|---|---|
| National GHG emissions | 100% | 76% | 87% | 98% |
| Population | 76% | 100% | 70% | 71% |
| GDP | 87% | 70% | 100% | 92% |
| Gross savings | 98% | 71% | 92% | 100% |
| **Number of operating CDM projects** | **95%** | **87%** | **85%** | **93%** |

Source: Based on 2,349 operating CDM projects and country characteristic indicators from the World Bank (WDI, 2012)

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