Technology transfer in the Clean Development Mechanism

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Abstract

Technology transfer is often mentioned as an ancillary benefit of the Kyoto Protocol's Clean Development Mechanism (CDM), but this claim has never been researched or substantiated. The question of technology transfer is important from two perspectives: for host countries, whether the CDM provides a corridor for foreign, climate-friendly technologies and investment, and for industrialised countries as it provides export potential for climate-friendly technologies developed as a consequence of stringent greenhouse gas targets. In order to better understand whether technology transfer from the EU and elsewhere is occurring through the CDM, and what is the value of the associated foreign investment, this paper examines technology transfer in the 63 CDM projects that were registered on January 1st, 2006. Technology originates from outside the host country in almost 50% of the evaluated projects. In the projects in which the technology originates from outside the host country, 80% use technology from the European Union. Technologies used in non-CO_2 greenhouse gas and wind energy projects, and a substantial share of the hydropower projects, use technology from outside the host country, but biogas, agricultural and biomass projects mainly use local technology. The associated investment value with the CDM projects that transferred technology is estimated to be around 470 million Euros, with about 390 coming from the EU. As the non-CO_2 greenhouse gas projects had very low capital costs, the investment value was mostly in the more capital-intensive wind energy and hydropower projects.

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1. Introduction

The Clean Development Mechanism (CDM) is one of the flexible mechanisms of the Kyoto Protocol and has two purposes: to assist non-Annex B in achieving sustainable development and to allow Annex B countries to comply with their Kyoto obligations through emission reductions generated in non-Annex B countries (UNFCCC, 1997). The CDM Executive Board, along with the Designated National Authorities in the host countries, are responsible for the fulfilment of those objectives, but in addition, numerous evaluations have been done on whether the CDM lives up to the expectations, whereby especially the sustainable development contribution of the CDM was questioned (see e.g. Ellis et al., 2006), as the additionality of the greenhouse gas emission reductions is thought to be sufficiently guaranteed through the stringent mechanism for registration with the UNFCCC. The flexibility in applying the sustainable development definition, and the prerogative of the host country to determine whether it takes place have led to a little transparent definition and to ambiguity on how the sustainable development criterion is handled (Cosbey et al., 2005).

In addition to whether sustainable development takes place, the CDM is often associated with the transfer of technologies from industrialised to developing countries. Much has been written about how the potential for technology transfer under the CDM might be enhanced, pointing at for instance the strategies of credit-purchasing governments (Aslam, 2001) or at mobilising synergies between private sector involvement and capacity building (Davidson, 2001). As the number of projects under the CDM is now on the rise, it is possible to go beyond the speculation on future improvements and evaluate the level of technology transfer place in the current the CDM project portfolio.

This paper focuses on two aspects of technology transfer: it first assesses in detail the origin of technology of the 63 CDM projects that were registered with the UNFCCC on 1st January 2006, and determine whether technology transfer took place. In addition, and based on the results on technology transfer assessment, a rough analysis of the size of exports from industrialised countries to the CDM host countries is given.

The latter question is relevant for two purposes. First, the outcome gives an indication of the foreign investments the CDM generates for cleaner technologies, and secondly, it provides an additional ground for the development of cleaner technologies in industrialised countries, and for gaining experience with them, in order to be able to export to countries that have not been willing or able to develop them, through the CDM.

Chapter 2 of this paper explains the methodology that is used in the analysis. Chapter 3 gives results for the technology transfer analysis, and Chapter 4 for the investment analysis. Chapter 5, finally, discusses the conclusions that can be drawn.

2. Approach for the technology transfer analysis

There is surprisingly little consensus on what technology transfer comprises. The literature shows a broad array of definitions (Wilkins, 2002; Kline et al., 2003). In this paper, we adopt the broad definition according to the IPCC (2000):

> *"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, NGOs and research/education institutions."*

Given the IPCC definition, in the context of this paper, we have identified a number of criteria that can be applied to registered CDM projects and that evaluate all aspects of technology transfer. Other projects looking at technology transfer often focus not so much the question *whether* technology transfer took place, but on the *effectiveness* of the technology transfer. In the context of climate change, for instance, criteria include 'whether emissions are reduced' or 'whether the local community is involved in the activity' (IPCC, 2000). As these criteria are already inherently positive for the CDM, given its requirements for emission reduction, additionality, public comment procedures, and sustainable development, we have not used those.

For this, the following criteria need to be evaluated:
1. Whether technologies deployed in CDM originate from outside the host country.
2. Whether the technologies that are implemented in CDM are indeed new or improved and do not represent business as usual in the host country of the project.
3. Whether the knowledge and capacity to implement the technology in the project is originating from outside the host country.

The evaluated CDM project portfolio consists of all registered CDM projects by January 1st, 2006. The total number of projects is 63, situated in 20 different countries. The Project Design Documents (PDDs) were used to obtain a detailed description of the project activity, including in some cases an assessment of whether technology transfer has taken place. Sometimes, the PDDs give sufficient information on the technology origin, but in other cases, the project developer was interviewed per email to obtain missing information.

After evaluating all projects, the projects that comply with the 1st criterion (i.e. projects that use technology from outside of the host country) the capital costs of the installations used in the projects are evaluated and the overall capital costs are evaluated. The resultant equals the turnover that companies from Annex-B countries have been able to make as a consequence of the CDM.

Although the approach is fit for the purpose of evaluating technology transfer in the CDM, it has a number of limitations. First of all, the criteria disregard technology transfer inside a country, e.g. from the one region to the other, or from urban to rural areas. This may be a significant flow, which is also illustrated by investment numbers - the lion's share of all investment in most developing country are domestic investments (Ellis et al., 2006). We therefore do not show the full, real technology transfer according to the definition in IPCC (2000), which does not explicitly require the crossing of country borders. However, for our purpose, which is to evaluate the extent to which the private sector in Annex-B countries can benefit from the technology pull generated by the CDM in developing countries, the criteria are fit for purpose.

Another limitation is the data availability, particularly for the 2nd and the 3rd criterion. In the case of the question whether the technology is 'new or improved', there is much room for interpretation, and information on the state-of-the-art or 'average' technology in specific countries is often hard to get by.

For the 3rd criterion, on the question whether knowledge transfer (or 'soft technology transfer') has taken place, uncertainties are even greater. Not only is the criterion itself rather subjective (e.g., in an extreme case, knowledge transfer could even occur by sending a user manual of an installation), the source of information is problematic, as we have to rely on the PDD only for this. Many PDDs do not mention 'soft technology transfer', and those who do use it to demonstrate additionality or ancillary benefits. Because the claim of knowledge transfer or capacity building cannot be evaluated independently, and the project approval is partly dependent on it, the writer of the PDD has an incentive to exaggerate the level of knowledge transfer or capacity building associated with his project. The reliability of the assessment of particularly the 3rd criterion is therefore reduced significantly.

3. Results of the technology transfer analysis

The 63 CDM projects that were registered on January 1st, 2006, were evaluated based on the criteria in Chapter 2. The projects in the portfolio of are in the sectors electricity, waste, industry, agriculture, thermal energy, and in the residential sector.

The technologies of the registered projects were biogas, bio-energy, hydropower, wind energy, fuel switch, and energy efficiency, all of which reduce CO_2, methane capture from swine manure and landfill gas capture (reducing CH_4), N_2O avoidance and HFC-23 destruction. The host countries were Argentina, Armenia, Bangladesh, Bhutan, Bolivia, Chile, China, Costa Rica, Fiji, Guatemala, Honduras, India, Mexico, Morocco, Nepal, Panama, Peru, Korea, South Africa and Sri Lanka (UNEP/Risoe, 2006). The project development and financing construction vary significantly across the project portfolio. While some of the projects were originated unilaterally, others were heavily financed by development agencies, were helped by World Bank funding, or had contracted buyers via national tender constructions before registration with the CDM Executive Board.

The emissions reductions per technology are summarised in Table 3.1.

Table 3.1 *Summary of emission reductions by technology in the 63 registered CDM projects by January 1st, 2006*

Technology	Number of projects	Share of number of projects [%]	Emission reduction [tCO_2-eq]	Share of total emission reduction [%]
Biogas	6	10	387,591	1.4
Biomass	10	16	302,735	1.1
Energy efficiency	1	2	6,580	0.0
Fuel switch	1	2	19,438	0.1
HFC-23 destruction	3	5	8,233,566	28.9
Hydropower	22	35	775,471	2.7
Landfill gas	10	16	2,712,395	9.5
Methane capture	3	5	410,378	1.4
N_2O destruction	2	3	15,111,165	53.0
Wind energy	5	8	573,013	2.0
Total	63		28,532,332	

As has been noted on many occasions (see e.g. Capoor and Ambrosi, 2006), the share of renewable energy projects in the total share of projects is significant in this snapshot of the CDM project portfolio, but low in the market share of Certified Emission Reductions (CERs) compared to the large-scale non-CO_2 greenhouse gas emission reduction projects; notably N_2O and HFC-23 destruction, but also landfill gas projects. Normally, a lower level of desirability and sustainable development contribution is associated with CDM projects that favour large-scale, industrial, non-energy-sector emission reductions. Particularly the low cost of HFC-23 projects (IPCC, 2005), the associated windfall profits on CERs and the perverse incentives such HFC projects provide for the production of ozone-depleting HCFC-22 have generated much concern. A large part of the projects in the portfolio uses technologies that originate from the host country, and therefore do not generate technology transfer as defined in criterion 1 (see Table 3.2). In the cases where the technology originates from outside the host country, it is mainly from the European Union, and a small part uses technology from the United States, Japan or Switzerland.

In almost 60% of the projects, furthermore, we could confirm that new or improved technology was used (criterion 2). The projects in the group that use new or improved technology included all the projects that met criterion 1 on using foreign technology. The projects that were new or improved, but also supplied from inside the host country, involved for instance the swine manure methane capture projects in Chile, and biomass projects in India.

In addition, according to the PDDs, almost half of the projects involved some degree of capacity building or knowledge transfer (criterion 3). This mostly involved the employment of local workers, who require training and courses to operate the technology.

The summary of the evaluation of the criteria is in Table 3.2 and in Figure 3.1.

Table 3.2 *Summary of results of the technology transfer criteria analysis*

Criterion	Result indicator	Number of projects meeting result	Share of projects meeting result [%]
1. Origin of technology used	Europe	23	37
	Host country	26	41
	Other (mainly Japan, US)	7	11
	No data	7	11
2. New or improved technology, new in the country	Technology transfer	37	59
	No Technology transfer	22	35
	Unclear	3	5
	No data	1	2
3. Capacity building or knowledge transfer required	Capacity building	29	46
	No capacity building	33	52
	Unclear	1	2
	No data	0	0

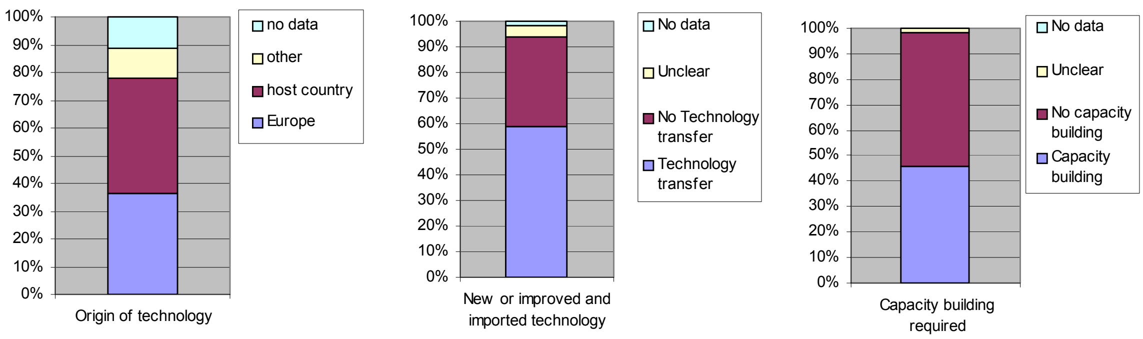

Figure 3.1 *Summary of results of the technology transfer criteria analysis in share of the projects*

Zooming in from the general numbers to the specific technologies and countries, it is observed that the origin of technologies is very widespread. The technology for landfill gas is mainly from the Netherlands and some local, for N_2O reduction mainly from France (for some: no data found), and for HFC-23 destruction from the Japan, the UK and Germany. Methane capture from swine manure in Chile is a locally developed technology.

In the power sector, hydropower is partly imported technology from the EU (Spain and France), Japan, Switzerland and the United States, and partly supplied by the host country (India, Peru, Sri Lanka). Wind energy technology originates from Spain and Denmark. Bio-energy for electricity is without exception from the host country.

For thermal energy, the biogas installations are partly from the host country, and partly there are no data available. For the one efficiency project, the technology is from the host country South Africa. The project that involves fuel switch in industry uses technology from Germany.
The technology transfer results per technology are summarised in Table 3.3.

Table 3.3 *Summary of technology transfer and origin of hardware per technology*

Technology	Number of projects with technology outside host country of total projects	Percentage of projects technology outside host country [%]	Origin of technology
Biogas	0 of 6	0	China, India
Biomass	0 of 10	0	India
Energy efficiency	0 of 1	0	South Africa
Fuel switch	1 of 1	100	Germany, United States
HFC-23	2 of 3	67	Germany, Japan, United Kingdom
Hydropower	12 of 22	55	China, Australia, France, India, Japan, Panama, Brazil, Peru, Spain, Sri Lanka, Switzerland, United States
Landfill gas	8 of 10	80	Belgium, Netherlands, Japan, France, Brazil, United States
Methane capture	0 of 3	0	Chile
N_2O destruction	2 of 2	100	France
Wind energy	4 of 5	80	Spain/Denmark

It is remarkable that many of the projects that might be able to comply with 'sustainability quality brands' such as the CDM Gold Standard (Ecofys, 2005) do not feature technology transfer. The small projects in terms of greenhouse gas emission reductions, energy efficiency, fuel switch in industry, biogas and small-scale biomass-based energy, use host country technology, whereas the large-scale projects, notably in the non-CO_2 greenhouse gases, use technology from the European Union or Japan. In the power sector, the picture is more mixed; although in wind energy, all projects of which the technology origin could be determined showed technology originating from the European Union, hydropower technology comes from all over the world. The origin of technology per country is shown in Figure 3.2.

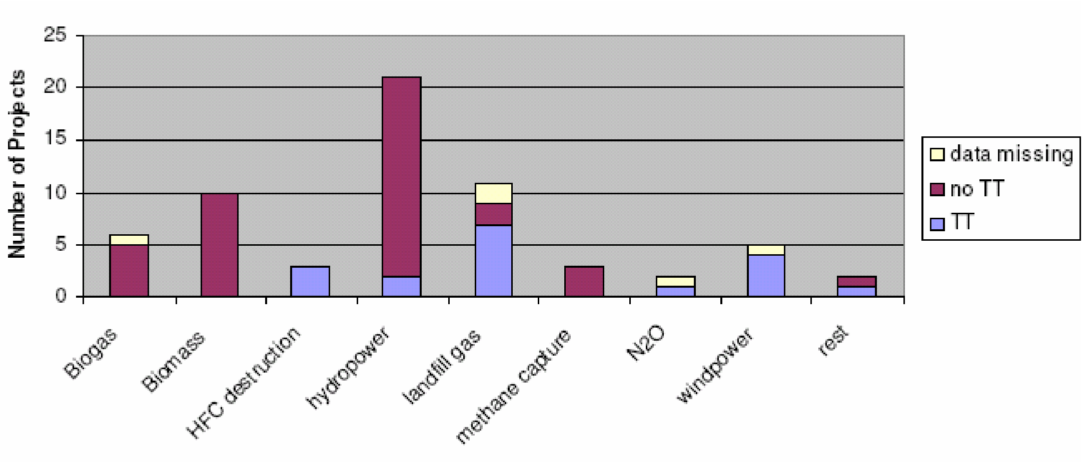

Figure 3.2 *Overview of for which technologies technology transfer takes place*
Source: Haake, 2006.
Note: For biogas, biomass, hydropower and methane capture, most of the projects use technology from the host country. For HFC and N2O destruction, landfill gas, and wind energy, most of the projects used technology from the European Union or Japan.

4. What are the international capital flows associated with CDM?

Even when the greenhouse gas reduction and the technology are known, the size of the investment is not necessarily obvious. For capital costs, the size of the installation is relevant, as opposed to the reduction in tonne CO_2-eq. For wind energy, for instance, the investment costs are expressed in the installed capacity (in €/MW) but the emission reductions on the produced electricity (so the unit is tCO_2/kWh). These units are not readily convertible, as a wind energy project with a load factor of 20% produces less electricity, and therefore reduces less emissions, that a projects with a load factor of 30%, which may be the case in good wind locations. The investment costs are calculated in €/kW, but one needs a significantly higher investment to reach the same GWh electricity production for a less favourable wind location. Similarly, run-of-river hydropower plants have a very different load factor from dam-based hydropower plants. For non-power projects, the investment costs have to be expressed in other units; per tonne of HFC-23 or N_2O destroyed, or per tCO_2 in the case of fuel switch.

The capital costs for the investment in this analysis are technology-specific but have not been made location-specific. This is a serious limitation as informed but general assumptions had to be made on projects that function under fairly diverse conditions. The analysis also only takes transfer of 'hardware' into account. The investment costs are calculated based on the size of the project and the greenhouse gas emission reduction, and on generalised assumptions on investment costs per unit size. Benefits occurring from soft technology transfer (such as knowledge, capabilities) are also not included. Table 4.1 shows the investment costs that are used for different technologies that were transferred. A pragmatic approach was adopted to evaluating investment costs, and was more often led by data availability than by what would be the most suitable metric for the investment costs. The numbers in Table 4.1 should therefore be regarded with much care, and only be used in a general way. Only the projects that meet criterion 1 (see Chapter 2 and 3) involve the transboundary movement of technology transfer-associated capital flows, and therefore only those projects are considered in the investment flow analysis.

The main uncertainties and assumptions are in the following steps and data:

- There are uncertainties in the technology transfer database to start with. For instance: the Dutch supplier of landfill gas technology uses turbines from Germany. This second-step is not taken into account.
- The investment metric has been generalised in many respects. For instance: the unit of € per MW for landfill gas projects is not the most appropriate - per tonne of waste would in principle be more suitable.
- The investment costs themselves originate from different data sources, and in many cases are generalised. Investment costs for hydropower projects, for instance, vary greatly depending on the project circumstances and the technology used.
- No ranges are given, only 'best estimates'.

Table 4.1 *Assumptions on metric and investment costs for technologies that are transferred under the registered CDM projects as of 1st of January 2006*

Technology	*Unit for investment costs*	*Investment costs*	*Reference and clarification*
Landfill gas	€/kW	1,200[1]	Based on report on http://www.nrbp.org/pdfs/pub08.pdf (1.5 million US$ for 1 MW), and the average GHG reduction per MW in the CDM registered projects of UNEP Risoe is 51.
Hydropower	€/kW	1,958	Investment costs for small-scale hydro from www.renewable-energy-policy.info - MEP tariffs - 2004-2005. It is assumed that 55% of the total investment costs of 3560 €/kW are 'technology costs' and are associated with tech transfer.
Wind power	€/kW	1,000	Investment costs for small-scale hydro from www.renewable-energy-policy.info - MEP tariffs - 2004-2005. It is assumed that some 91% of the total investment costs of 1100 €/kW are 'technology costs' and are associated with tech transfer.
HFC-23 destruction	€/tHFC-23/yr	15,000	Based on 'expert judgment' of € 3 million for 200 tHFC-23/yr (Harnisch and Hendriks, 2000)
N_2O destruction	€/tN_2O/yr	176	Based on the PDD of the Korean CDM project, which claims an offer by Rhodia of France of € 6.5 million for 29,500 tN_2O
Fuel switch (coal to gas)	€/tCO_2-eq/yr	23	Based on the PDD of the sole coal-to-gas project (for steam production) in the portfolio: 550 000 US$ for reduction of 19,438 tCO_2-eq

According to the data in Haake (2006), transfer of hardware technology took place in 30 of the 63 projects. However, because in several projects the technology originated from more than one country, the total number of entries in our analysis is 34. In the case of more than one country, it is assumed that the investment value is shared equally among the technology-exporting countries.

Table 4.2 shows the greenhouse gas emissions reductions per exporting country and per technology in tCO_2-eq per year. The total is 25.4 MtCO_2-eq per year, which is 89% of all emission reductions of registered CDM projects on January 1st, 2006. EU Member States supply technology associated with 23.5 MtCO_2-eq/yr emission reduction, other countries (mainly Japan) supply the remaining 1.9 MtCO_2-eq/yr.

[1] Most of the investment costs are for the turbine, converting the landfill gas in to usable electricity. Many projects, however, don't make electricity and only claim the emission reductions from the methane flaring. In the case of flaring, the investment costs are: 0.35*1200 because the electricity production is 65% of the total investment cost.

Table 4.2 *Greenhouse gas emission reductions per exporting country and per technology*

Technology exporting country (# of projects)	Landfill gas	Hydro power	Wind energy	Fuel switch	HFC-23	N_2O destruction	Total GHG reductions through transferred technology
Belgium (2)	87						87
Denmark (1)			26				26
France (8)	70	135				15,111	15,316
Germany (3)		30		10	3,834		3,873
Netherlands (3)	752						752
Spain (7)		48	366				414
United Kingdom (1)					3,000		3,000
USA (5)	279	30	26	10			345
Japan (3)	135	0.3			1,400		1,535
Switzerland (1)		30					30
Total (34)	1,323	274	417	19	8,234	15,111	

Note: Numbers in $ktCO_2$-eq/yr. The numbers between brackets indicate the total number of projects that transfer hardware technology from the country. Columns and rows may not add up correctly because of rounding errors.

From the above, the detailed project data in our databases, and using the investment costs in Table 4.1, the total investment value per technology and per exporting country can be calculated. The numbers are given in Table 4.3.

Table 4.3 *Investment costs per technology and country for the registered CDM projects as of 1st January 2006*

Technology exporting country (# of projects)	Landfill gas	Hydro power	Wind energy	Fuel switch	HFC-23	N_2O destruction	Total
Belgium (2)	0.7						0.7
Denmark (1)			13				13
France (8)	0.6	83				8.6	92
Germany (3)		29		0.2	4.9		34
Netherlands (3)	9.1						9.1
Spain (7)		23	212				235
United Kingdom (1)					3.8		3.8
USA (5)	8.0	29	13	0.2			50
Japan (3)	2.0	0.1			1.8		3.9
Switzerland (1)		29					29
Total (34)	21	194	238	0.4	11	8.6	472
Share in total	4%	41%	50%	0%	2%	2%	

Note: Numbers are in million €, and columns and rows may not add up correctly because of rounding errors.

Renewable energy technologies dominate the investment portfolio in the registered CDM projects where hardware technology is transferred. Spain, primarily through its supply of wind energy, is able to export the highest value of technology. France also has a large number, primarily through hydropower. The United States, Germany and Japan also export a substantial value of technology. Denmark, the Netherlands, the United Kingdom, Switzerland and Belgium all have small shares. The results per country are in Figure 4.1.

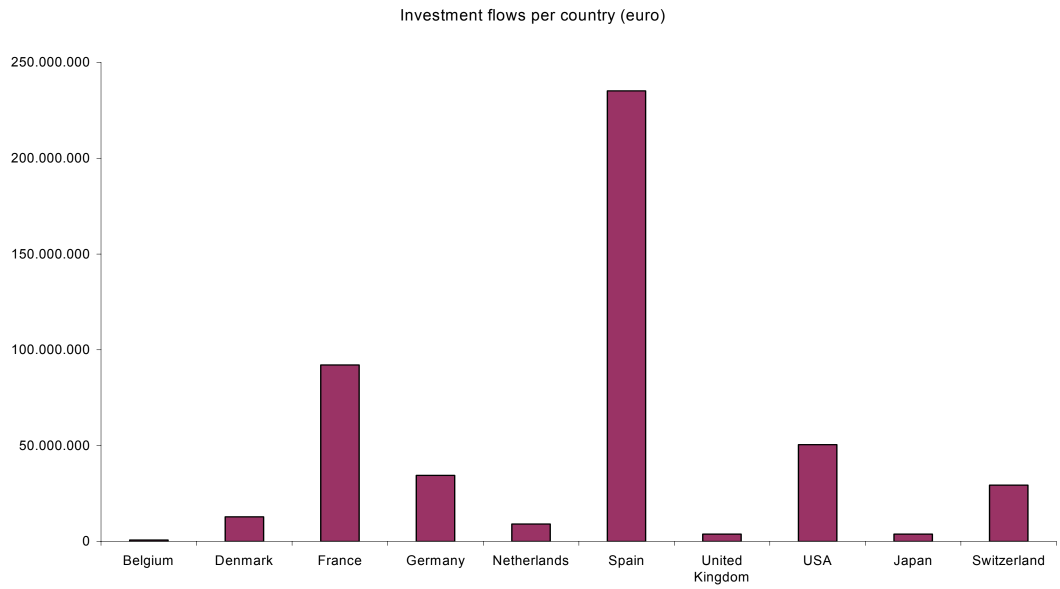

Figure 4.1 *Value of investment per technology-exporting Annex-B country used for CDM projects in €*

5. Discussion and conclusion

We have analysed the portfolio of registered CDM projects on 1st January 2006 to clarify the extent of technology transfer taking place in the CDM. We have found that a significant share of the projects uses technology from outside the host country, notably in large-scale non-CO_2 greenhouse gas projects, and in wind energy. The lion's share of the technology used in the projects originates from either the EU or the host country. In most of the projects, new or improved technologies were used, and in many, knowledge transfer and capacity building took place, although these numbers are uncertain. It does confirm the need for capacity building associated with the transfer of new technologies.

The EU exported technology in over one third of the projects registered under the CDM in the beginning of 2006, notably in non-CO_2 greenhouse gases, wind energy and some of the hydropower projects. In bio-energy, thermal/efficiency and some hydropower and landfill gas projects, much of the technology was locally produced. In general, technology transfer takes place more in projects that reduce non-CO_2 greenhouse gases than in renewable energy and energy efficiency projects. The exception is wind energy, for which all projects used technology from the EU.

The value of the investment in technologies originating from industrialised countries is estimated at some € 470 million, of which 390 from the European Union. Most of this is for renewable energy: about half is wind energy, 40% is hydropower, and the contribution of non-CO_2 greenhouse gas reducing projects is very small: 4, 2, and 2% of the total for landfill gas, HFC-23 and N_2O, respectively. The investment analysis is associated with many uncertainties and assumptions. The numbers should therefore be taken as an approximation of the actual benefits for Annex-B companies in the CDM.

How do these numbers compare to other investment flows? Compared to the total value of CERs generated at the same moment (assuming a price of 5 €/tCO_2-eq and the reductions as in Table 3.1) of around € 140 million, the capital value of equipment flowing from the industrialised countries to CDM host countries is significantly higher. Compared to total foreign direct investment, however, which amounted on the order of some € 50 billion in 2002 (Ellis et al., 2006), the investments associated with CDM appear to be small[2].

It is remarkable that the allegation that CER-buying countries sponsor their own private sector through buying CERs only from projects that use national technology is not supported by the data above. The large buyers of CERs, such as the Netherlands, Japan and Italy, are not the countries that export the highest value of technology to the host countries for CDM projects. It should also be noted that the United States, not a Kyoto Party, has exported technology valued at around € 50 million; around 10% of the total export value for CDM projects at the time.

What is the potential for extrapolation of these numbers to the more recent CDM portfolio, which throughout 2006 has grown significantly? Several developments have taken place that will significantly influence the numbers presented above, both in the direction of more technology transfer and in the direction of less. First of all, the number of projects has soared, as well as the number of technologies. As we have not elaborately analysed these new technologies, we can only speculate about their origin, but given the rise in technologies that are widely used in Europe and Japan, particularly in the renewable energy and industrial efficiency sectors, it can be expected that the potential for technology transfer (and the export potential for companies in those countries) to developing countries has not been exhausted.

2 The number of € 50 million is based on the sum of the flows of 'direct investment' and 'other private flows' in Figure 1 in Ellis et al. (2006).

Secondly, and contradicting the first point, there is a trend towards the development of high-technology industries in particularly emerging economies, such as wind turbine industries in India and China. Although these industries still have to gain experience, their location gives them an advantage in terms of costs, and this is likely to increase their market share in the CDM. The balance of these developments might be that the amount of exports of climate-friendly, CDM-compatible technologies from industrialised countries will increase, but the projects without technology transfer, or, for that matter, with non-Annex-B to non-Annex-B technology transfer, will also rise. The extent of these increases will depend on the post-2012 regime, and the market that it will provide for the CDM.

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