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Can the CDM bring technology transfer to developing countries?

An empirical study of technology transfer in China's CDM projects.

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Can the CDM bring technology transfer to developing countries?
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Abstract

China has undertaken the greatest number of projects and reported the largest emission reductions on the global Clean Development Mechanism (CDM) market. As technology transfer (TT) was designed to play a key role for Annex II countries in achieving greenhouse gas emission reductions, this study examines the factors that have affected the CDM and TT in China. The proportion of total income derived from the Certified Emissions Reductions (CER) plays a key role in the project owners' decision to adopt foreign technology. Incompatibility of CDM procedures with Chinese domestic procedures, technology diffusion effects and Chinese government policy all contribute to the different degrees and forms of TT.

Key Words*:* technology transfer; technology diffusion; Clean Development Mechanism (CDM); Certified Emissions Reductions (CER); Chinese policy.

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Abbreviations and Acronyms

CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CMM	Coal mine methane
CO_2	Carbon dioxide
CWHR	Cement waste heat recovery
DNA	Designated National Authority
DOE	Designated Operational Entity
EB	Executive Board
GHG	Greenhouse gas
HFC	Hydro fluoro carbon
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual property rights
IRR	Internal return rate
N_2O	Nitrous Oxide
NDRC	National Development and Reform Commission
NGCC	Natural gas combined cycle
PDD	Project deign documents
TD	Technology diffusion
TT	Technology transfer
UNFCCC	United Nations Framework Convention on Climate Change

Introduction

Developing countries are estimated to account for approximately 70 % of the increase in global carbon dioxide (CO_2) emissions for the period 2002 to 2030 (OECD, 2002). Given that CO_2 emissions from fossil fuels account for the dominant share of anthropogenic greenhouse gas (GHG) emissions, transfer and deployment of lower- or non-CO_2 emitting energy technologies will be required “on an unprecedented scale” (IEA, 2005). Among the three flexible mechanisms of the Kyoto Protocol, the Clean Development Mechanism (CDM) is the only one that permits developing countries to participate in global mitigation efforts. The stated purpose of the CDM is to reduce compliance costs for industrialized countries while encouraging sustainable development in poorer nations by introducing more environmentally friendly technologies to developing countries. Technology transfer (TT) is, therefore, a crucial component of clean development in general and its governance can be expected to influence the extent to which its potential is realized. Looking at the policy environment for technology transfer in a country as important as China makes an important contribution to broader debates about the governance of clean development (Newell et al., 2009).

Since 2003, there have been more than 4,200 CDM projects, which are expected to be credited with more than 2.9 billion tons of CO_2 emissions reductions (UNFCCC, 2009a). However, the impact of these projects on TT and subsequent technology diffusion (TD), which will be essential for developing countries to achieve higher mitigation targets, is inadequately understood[1]. China has approved 1,846 CDM projects with 450 of these registered by the CDM Executive Board (EB) as of January 16, 2009 (NDRC Climate Change Department, 2009). By the end of the Kyoto Protocol’s first commitment period in 2012 these projects will enable China to issue about 0.16 billion tons CO_2 equivalent credits annually; approximately 57% of total annual global emissions reductions under the CDM (UNFCCC, 2009b). As the largest emitter of GHG, China plays a pivotal role in shaping global climate change mitigation outcomes though its per capita GDP is similar to other developing nations (State Council, 2006b). With an estimated 130 million to 195 million people living in poverty, China lacks adequate financial capacity to upgrade its energy sector for the sake of GHG reductions (Chen and Ravallion, 2008). Therefore, internationally assisted TT is essential to help China realize mitigation targets.

Both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol include provisions for developed countries to take actions that stimulate TT to developing countries. China has drawn attention to this numerous times in the diplomatic arena (UNFCCC, 1992; UNFCCC, 1998). As an Annex II country defined by the Kyoto Protocol, China participates in GHG emissions mitigation in a ***measurable, reportable and verifiable*** manner only through the CDM. Although the CDM EB does not make technology transfer a compulsory condition for project eligibility, it may contribute to TT by financing emission reduction projects that use technologies currently not available in the host countries (UNFCCC CDM EB, 2006a).

Chinese leaders have expressed a desire to obtain financial and technological assistance through the CDM. However, proven TT as a result of CDM projects remains controversial. Previous studies have teased apart the theoretical impact of competitive markets and trade on incentivizing TT in the CDM (Hagem, 2006; Mukherjee and Rübbelke, 2006; Milloc, 2002: 449-466) as well as proposing several options to improve TT effectiveness in future CDM regimes (Teng et al., 2008). While useful, these studies cannot predict actor motivations, sector differences and other important complicating

[1] Technology spillovers are neither automatic nor costless but they require both adoption capabilities and transaction payoffs.

factors. Empirical studies have investigated the role of TT in CDM, but have not considered how CDM can create TT nor have these studies sufficiently focused on China, i.e. through field studies and interviews (Youngman et al., 2007; Netsource, 2006). Given China's preponderance of CDM projects and GHG emissions and the pending Copenhagen accords, there is clearly a need for a thorough understanding of TT in Chinese CDM projects and the motivations of all actors.

For the purposes of this study, we consider technology transfer in CDM projects in China. We seek to understand: How does TT vary by economic sector? How do incentives created by CERs and the availability of local technology affect TT? What roles do transaction costs and host government policy play in promoting or hindering TT? How do TT and TD interact? And what are the future prospects for TT?

Research approach

CDM project design documents (PDD) and their appendices from the UNFCCC databases were analyzed to determine TT occurrence, type of technology (e.g. equipment or know-how, or both) employed, who supplied the technology and justifications for adopting foreign technology or not. In terms of selection of CDM projects, all Chinese chemical decomposition projects (HFC23 and N_2O), methane utilization, cement waste heat recovery (CWHR) projects, and wind power projects in the UNFCCC CDM pipeline were chosen [that is, the projects approved by Chinese Designated National Authorities (DNAs)] by March 1, 2009[2]. These selected project types are representative in terms of CER income differences, which serve as most important incentives in terms of TT facilitation. They also represent different technological scenarios across sectors in China, for example, whether there is strong domestic technology that can substitute foreign technology. Also, the projects differ in their positions with respect to Chinese national industrial policies. Project site visits and interviews of all actors involved in CDM projects[3] were conducted between December 2008 and April 2009 in order to understand non-explicit factors affecting TT in China's CDM projects.

Definition of technology transfer in CDM projects

Definitions and different levels of TT vary by scholars and authorities. Some experts discuss technological capacities as occurring at three levels, namely the basic level (know-how), intermediate level (know-what), and advanced or innovative level (know-why) (Lall, 2002; Muller, 2003; Hansen, 2008).

Basic level technology capacities have the following properties:

- Capabilities to use, operate and maintain the technological equipment, devices, machinery, etc. subsequent to implementation of the technology, including undertaking replacement and repair of minor components.
- Capability, primarily concerning the respective operators, to secure and maintain an efficient level of productivity (at best, at its design levels of performance).

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[2] Selecting Designated National Authorities (DNA) approved projects instead of the registered ones is not only because the number of the latter is too small but most importantly because the former represent more wholly the complete process of the CDM CER realization process.

[3] UNFCCC CDM officers, Chinese government CDM officials, Chinese CDM researchers, international carbon traders and CDM developers, government and private Chinese CDM developers, Chinese CDM project owners, technology providers and Chinese CDM Information Center personnel.

Properties at the *intermediate level* are:

- Capability to replicate and or independently undertake complete implementation, including possibly fabrication of technological components, technological subsystems or complete systems.
- Capacity to independently undertake incrementally minor adjustments, modifications, improvements, optimization, etc. in relation to specific application requirements and contexts.

Properties at the *advanced level* are:

- Capability to generate more substantial changes and developments of the technological components, technological subsystems or complete systems in question.
- Capability to undertake reconfiguration and redesign of the basic technology outlay, and to develop new designs or elements of the system, or of the complete system, including possibly to continuously optimize system performance through engineering research and development related activities.

The Intergovernmental Panel on Climate Change (IPCC) defines TT 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, NGOs and research/education institutions," (IPCC, 2000). CDM project participants' general interpretation of TT in the PDD: "means to use equipment and / or knowledge not previously available in the host country" (UNFCCC CDM EB, 2006b). In Section A.4.3 of the PDD "Technology to be employed by the project activity," the 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)," (UNFCCC CDM EB, 2006b). Therefore, the TT defined in CDM PDDs refers to the transfer of equipment and basic level technology capacity (know-how). However, in the language of the Chinese government, the TT it expects to obtain does not coincide with the basic level of technology capacity transfer. Instead, it refers to the higher (intermediate and advanced) levels of TT. This is demonstrated in the Chinese TT strategies discussed below. This might explain the conflicting policy impact upon TT in CDM projects.

Chinese government policy affecting technology transfer in CDM projects

In Chinese government documents, the CDM is often cited as a means not only to obtain financial assistance for Chinese sustainable development, but also to obtain advanced technology from Annex I countries. Doubtless, the latter objective is the more important (Gao, 2008). However, in the real world scenario, the relationship between government policy and CDM in promoting TT is a rather complex one. Although CER income through CDM can facilitate TT, and TT fits the general goals for China's sustainable development, the project-based nature of CDM can only introduce foreign equipment and training of operational skills, while the Chinese government's policy priority is to realize TD that is at the intermediate level or advanced level of TT through localization of foreign advanced technology. As TT in CDM projects mainly belongs to the low level of TT, in the form of importing individual foreign equipment and operating skills, it is not only costly but may hinder Chinese local substitute technology from being developed (State Council, 2006a). Therefore, when we look into the role of Chinese government policy for TT in CDM projects, we find different policy tools with mixed effects on TT in CDM projects.

The impact of the Chinese government's national grand development strategy on TT

The Chinese government's national grand development strategy creates a favourable policy environment that stimulates both the public and private sectors to develop low emitting projects that meet eligibility criteria for CDM. This produces an overall policy environment in which TT can flourish. For instance, the Chinese government's "Eleventh Five Year Plan" set the target of lowering energy intensity by 20 % from its 2005 level to 2010 (People's Congress, 2006). The government promulgated the Renewable Energy Law in 2005, which provided the legal foundation for the government to promote renewable energy research, development and deployment as national development priorities, assign targets for local government to fulfil and provide favourable policy leverages (People's Congress, 2005). The Chinese government also issued an "Eleventh Five-Year Plan" for some specific sectors such as "the Eleventh Five-Year Plan for CMM Development and Utilization" to increase recovery of coal mine methane (CMM) to 10 billion m^3 in 2010 (NDRC, 2006c) and "the Eleventh Five-Year Plan for Renewable Energy Development" setting the target of increasing renewable energy from 7.5 % in 2005 to 10 % by 2010 in total national energy consumption (NDRC, 2008). These national grand development strategies obviously provide the right incentives for both the local government and business to promote energy conservation and efficiency, and renewable energy projects, which will be significant in carbon emission reductions. This process naturally leads to a favourable environment for TT to occur in CDM projects.

Chinese regulations and policies that have a direct impact on TT in CDM projects

In order to support the equipment manufacturing industry and prioritize energy conservation technology, the China State Council issued "Opinions of the State Council on Speeding up the Revitalization of the Equipment Manufacturing Industry" in June 2006 and a series of measures were proposed (State Council, 2006a). Among them are differentiated fiscal and tariff regulations on foreign technology: Only the shortlisted advanced equipment that has no domestic substitutes is eligible for exemption from import tariffs and value-added tax returns. Those who have domestic substitutes and need to import components for the equipment are eligible for favourable taxation treatment, while importers of complete technology systems are not (Ministry of Finance et al, 2007). These policies are aimed at encouraging foreign technology providers to move their production to China and increase the local content of their technology. Tariffs levied on foreign equipment are usually 10 %. This tariff level does not make the low carbon equipment more competitive than other imported commodities. Also, the tariff on foreign equipment is disadvantageous when it competes with low-cost local equipment, and reduces the incentives of project owners to deploy foreign technology. As CDM is a project-based market mechanism, the TT mostly is realized through importation of equipment and related operational training.

To spur foreign technology providers to localize their advanced technology, the Chinese government uses the local content level requirement as leverage. A typical case is China's Wind Concessions. Beginning in 2003, NDRC launched a program to auction off the rights to development of large wind farms (Wind Concessions) that include cumulative local content requirements over time[4]. The requirements began by mandating 50 % local content in 2003, increasing to 70 % in 2004. In selecting winning projects under these rules, local content percentages (above the minimum standards of 50 - 70 %) are a key determinant of the evaluation. They were responsible for 35 % of

[4] This Chinese government-run bidding program encourages domestic and international companies to develop wind projects and was first utilized to promote large-scale wind farms. The program grants companies the right to develop the selected project site and includes a 25-year power purchase agreement, guaranteed grid connection, financial support for grid extension and access roads, and preferential tax and loan conditions.

the score used in evaluating bids in 2006, up from 20 % in 2005. In addition, the 70 % local content requirement now applies not only to the government-run wind concessions, but also to all wind farms being developed in China (Lewis, 2007)[5].

These local content stipulations are causing foreign firms interested in selling wind turbines in China to develop a manufacturing strategy directed toward meeting the requirements. Consequently, many leading international wind turbine manufacturers either establish local manufacturing facilities or assembly facilities for Chinese-made components. The policy seems to have been quite successful so far. All the foreign owned wind turbine companies met the Chinese local content requirement. The Chinese owned companies flourished from a handful to more than a dozen key producers. Some of them obtained the intellectual property rights (IPR) through their cooperation with foreign turbine producers (Lewis, 2009). The local and joint venture companies' turbines increased their share of China's cumulative wind power capacity from 15.4 % to 84.6 % by the end of 2008 (Shi, 2003 - 2008), (Fig. 1). However, the local content requirement does not promote a comprehensive form of TT that includes the transfer of advanced or innovative (know-why) technology, because only two of the Chinese wind turbine producers have acquired independent property rights to turbine technology (Lewis, 2009).

For project-based CDM, such policy leverage over TT is a double-edged sword. On the one hand, it can protect the local technology providers by strengthening their market competence. It may also stimulate foreign technology providers to seek cooperative agreements with local producers and move their production to China by selling licenses or meeting the local content requirement. This strategy reduces the cost of deploying foreign technology and therefore accelerates the diffusion of more efficient technology. On the other hand, if the foreign providers do not choose the strategy of localization, the unfavourable tariff might serve as an incremental cost hurdle for the deployment of the already high priced foreign technology. This suggests that some companies operating under stringent financial conditions will choose local substitute equipment. Considering that foreign technologies generally are 30 % more efficient, this might reduce GHG reduction opportunities.

The Chinese government as a broker in TT

Apart from policy leverage, the Chinese government is also involved as a broker in facilitating TT. As shown in the TT case of cement waste heat power generation, the government functioned as a broker to introduce novel technology into the demonstration stage in China, lowering costs and risks. The success of the demonstration led to the future introduction of ten lines of the same technology into deployment facilitated by income from the CDM. Later technology is diffused into the national market; with further innovation, the localized technology reaches the global industry's leading level.

[5] Local content requirements have been in place in China's wind power industry for many years. Wind farm projects approved by the National Development and Reform Commission (NDRC) during the Ninth Five-Year Plan (1996-2000) required that wind turbine equipment purchased for these projects contain at least 40 percent locally-made components (Lewis, 2007).

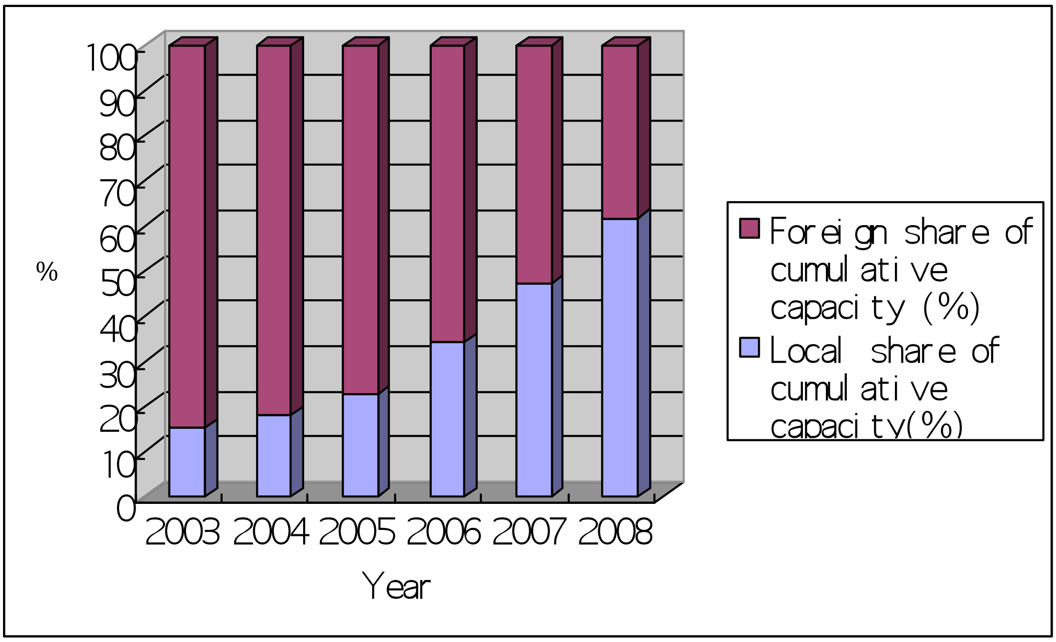

Figure 1: Local and foreign share of China's wind turbines market over time (Shi, 2003 - 2008)

Another form of government brokerage is the model of "binding bids" in the TT of gas turbines in the NGCC. The Chinese government organized interested gas fired plant investors and bundled their equipment for bidding from 2001 (NDRC, 2001). The tendering enterprise was to include a Chinese partner and a foreign partner. The foreign partner had to agree to transfer the technology of gas turbines to the Chinese partner and achieve a specified goal of local content. All major domestic and international power plant equipment producers participated in the bids for gas turbines. Three joint bidding unions were: Dongfang Electric with Mitsubishi, Shanghai Electric with Siemens, and Harbin Power Equipment with GE Energy (Teng *et al,* 2008). In the agreement between Dongfang and Mitsubishi, the two parties agreed on a final target of 67 % local content. The remaining 33 % high temperature core components of gas turbines, such as the combustion chamber and turbine blades, will be transferred to a joint venture company controlled by Mitsubishi (51 %) (Dongfang Electric Company, 2005). The local content level in the turbines had reached 46.5 % and 58.5 % by 2005.

In the Harbin Power Equipment cooperation with GE Energy, the localization process was even faster. By February 2009, Harbin had produced a 390H type gas turbine with a capacity of 400MW with 100 % local content (XinhuaNet, 2009). But compared to coal fired power, gas power is still inferior. CDM provides major financial assistance in compensating for the higher cost.

The above analysis shows that in China's nationally prioritized TT areas, the government's financial, tariff and regulatory policies and direct involvement as a broker have dominated the form and process of TT. Due to the small margin of financial income from CER, the mechanism serves as a minor factor in affecting the project owner's decision.

The impact of Chinese CDM regulations on TT

Based on the logic that the emission reduction resource is owned by the state, the government collects "royalty fees" from the revenue of CER transfers. The CDM projects in priority areas such as energy efficiency improvement, development and utilization of new and renewable energy, and methane recovery and utilization pay a 2 % fee from their CER revenues while the non- prioritized projects such as HFC destruction and N_2O abatement pay 65 % and 30 % respectively (NDRC, et al., 2005; MOF and SAOT, 2009). The fee China imposes on CDM projects is innovative, because it directs investment into China's priority areas and because it diminishes the comparative disadvantage of renewable energy, energy conservation and efficiency projects, which are not taxed highly in comparison to N_20 and HFC projects. The much lighter fee burden in turn improves the Internal Return Rate (IRR) expectation of the project. The improved financial condition of project owners informs their decision whether or not to deploy higher cost foreign technology.

The Chinese government creates a carbon price floor for the CER contracts between CDM project owners and international carbon traders that guarantee CDM project owners a minimum CER income that will help overcome the cost hurdle for TT. The rationale is based on the idea that CER income is not just the project owners' asset but also a national resource. Also, the price floor prevents project owners from being underpaid due to their disadvantageous position in access to the international carbon market. The price floor has risen from about $6 initially to $10.5/t$CO_2$. Although the international carbon traders have complained at times of a soft carbon market, it guarantees the CER income which will in turn help to overcome cost hurdles should TT occur (Chinese climate change officials, 2008; International carbon traders, 2008).

National government regulations regarding qualification for project ownership of CDM do restrict the possibility of TT though. According to "Measures for Operation and Management of Clean Development Mechanism Projects in China" issued by NDRC and three other ministries, only Chinese companies or Chinese holding companies are eligible for CDM projects in China (NDRC et al., 2005: Article 24)[6]. The logic behind this rule is that CER income is a national asset and does not belong to private companies. Therefore, foreign companies should not profit from the income of CER. This rule ensures that Chinese firms keep a controlling interest, but it limits risk management possibilities and repatriation of profits for foreign partners. For this reason, foreign companies currently are mainly found as simple buyers of CER generated by CDM projects that have been conducted by Chinese companies and their respective consultancies. Projects that are only implemented to reduce greenhouse gases, e.g. landfill gas projects, which are more in need of foreign financial and technical assistance than projects for which CDM financing plays a marginal role, are thus hampered by the 51 % Chinese ownership rule. Although a foreign-owned firm would not necessarily introduce foreign technology to its projects, the possibility of such TT is much higher both in terms of financial capability and technological ability, and this restriction obviously hinders TT in CDM projects (Schroeder, 2009; NDRC Climate Change Department, 2008).

TT is not considered in the Chinese DNA's evaluation of a CDM project. Because the CDM EB does not have an obligatory requirement for TT in CDM projects, TT is not taken into consideration by the Chinese DNA in its evaluation of a CDM project. As proof of additionality is the basis for registration, the introduction of a foreign technology increases the difficulty of establishing its reliability in the PDD due to lack of reference. On the other hand, foreign technologies might encounter problems in adapting to local conditions, which would increase risk to CER incomes. Therefore, the government does not encourage deploying international technology that is new to Chinese conditions in CDM projects (Chinese CDM researchers, 2009).

[6] A Chinese holding company refers a minimum of 51 % of the company owned by a Chinese entity and foreign ownership up to 49 %.

In conclusion then the Chinese government's policies affecting TT in CDM are mixed and sometimes contradictory. Generally, China creates a favourable policy environment for TT in CDM projects. But since the national priority of TT is not completely congruent with the form of TT in CDM projects, the national policy does not provide sufficient incentives for TT and even creates some hurdles that might hinder TT in CDM projects.

Findings from analysis of CDM project design documents: Factors in facilitating and retarding technology transfer

In the analysis of the CDM PDDs, all the HFC23 (11) and N_2O (42) decomposition projects, CMM utilization projects (59), CWHR projects (89) and wind power projects (271) in the CDM pipeline by March 1 2009 are covered[7]. By analyzing all the PDDs and their appendices, percentage of TT among the projects, IRR differences caused by CER differences, the chance of domestic technology substitutions of the foreign technology, efficiency and cost differences between local technologies and foreign ones are considered (Table 1).

By analyzing Section A.4.3 of each PDD, whether TT has occurred in the project or not can be ascertained. The forms of TT can also be identified. The most usual form for TT in CDM projects is adopting the foreign equipment along with training in operational knowledge. Therefore, the TT in regard to the level of technology capacity falls into the category of the basic level (know-how), instead of intermediate level (know-what), and advanced or innovative level (know-why). In Table 1, we can see different percentages of TT occurring in different sectors. The N_2O and HFC23 decomposition projects have the highest percentage of TT in the form of foreign equipment and training of operational know-how. Wind power, CMM utilization and CWHR projects have 38.2 %, 28.8 % and 7 % of TT respectively (Table 1). What are the factors that lie behind these different levels of TT?

Only with sufficient incentives and assurances (e.g. income from CER) will project owners buy technology in order for TT to occur (IPCC, 2000). Therefore, it is important to evaluate whether carbon values are providing sufficient monetary incentive for key technologies to be deployed in CDM projects. Although in many cases carbon value does not have a large impact on overall project economics, it may help projects overcome IRR hurdles or to obtain needed financing. As shown in Table 1, projects with high CER income also have high rates of technology transfer. This is most evident with respect to HFC23 and N_2O decomposition, where CDM CER income is the only motivation for the project owners. Because of their much higher global warming potential (1 HFC23 = 1170 CO_2; 1 N_2O=310 CO_2), destroying these gasses produces a substantial potential CER income, which is important as these projects have no other deliverable. The 11 HFC23 decomposition projects are only 0.57 % of total Chinese CDM projects. However, they constitute 17.29 % of Chinese annual CDM emission reductions. On the other hand N_2O abatement projects comprise 1.29 % shares of total projects but 6.37 % of total annual emission reductions (China CDM Database, 2009a and 2009b). The IRR in such projects is so high that CDM developers are unlikely to state the cost formally and do not use the term IRR in their project description documents.

[7] Besides the CDM PDDs and their appendices, the technology transfer statistics on wind power CDM projects also refer to China Wind Power Association statistics which are more precise in terms of the installation of power capacity, as all the wind power projects in China applied for CDM.

Table 1. Technology transfer in different types of CDM projects (March 1, 2009)[8]

Type of projects	Percentage TT in CDM projects	Project objectives	National policy facilitation[9]	Project IRR differences[10]	Indigenous tech substitution opportunity	Foreign tech vs. indigenous tech in cost	Foreign tech vs. indigenous tech in efficiency
HFC23 (11)	91%	GHG reduction	low	0.1-0.2$/t COST	weak	NA	NA
N_2O (42)	100%	GHG reduction	low	0.8$/t COST	NA	NA	NA
CMM utilization (59)	28.8%	Energy Efficiency +GHG reduction	high	7-27%	high	RMB7,000/KW Vs RBM4,000/KW	30%
Cement waste heat recovery (89)	7%*	Energy efficiency+ GHG reduction	high	5-7%	high	RMB18,000-22,000/KW Vs RMB10,000/KW	25%
Wind power (271)	38.2%	New clean energy+ GHG reduction	high	2-2.5%	high	RMB10,000/KW Vs RBM7,000/KW	30%

Apart from high CER income, the additionality for these projects is certain which means a much higher probability that CERs will be issued from the CDM EB; that is, the high CER income can be harvested with very little risk. Thus far, HFC 23 and N_2O projects have registration rates of 100 % and 48 % respectively; figures that are much higher than the average Chinese registration rate of 24.3 % (UNEP Risø Centre, 2009). Obviously because CER income is high and certain, buying foreign technology does not impose a significant financial burden on the project owners. Also, international carbon traders are exceptionally enthusiastic about these low risk projects and are willing to prepay a certain portion of the future CER price to allow the project owners to purchase foreign equipment, which has seldom occurred in other types of projects (Chinese CDM Consultants, 2009; International carbon traders, 2009).

[8] Based on the author's own analysis and adaptation from the PDDs and internal rate of return (IRR) documents and other related documents publicized on UNFCCC website: http://cdm.unfccc.int/Projects/projsearch.html. Also based on the author's interviews with scholars, CDM project consultants, international carbon traders, international equipment providers and project owners from December, 2008 to April, 2009.

[9] "National policy facilitation" means "whether there are national government policies that facilitate the program". In CMM utilization, CWHR and wind power projects, government policy facilitation factor composes one of the key incentives in the project owners' decision to adopt foreign technology or not beyond the CER income factor. This will be discussed later in the paper.

[10] As the CER income from the HFC23 decomposition and N2O abatement projects is disproportionately larger in comparison with their investment, the PDDs do not provide concrete figures of the cost. The cost of the GHG reductions in such projects was estimated through communications with some Chinese CDM project owners and developers. The calculation of the internal rate of return (IRR) differences with and without CER income in CMM utilization, CWHR and wind power projects was based on their PDDs and appendices. Different calculations have been made of CDM contributions to project IRR. The OECD estimates are based on a carbon price of CO_2e, the increase in a project's IRR has been estimated at 0.8 - 2.6 % for hydro, 1 - 1.3 % for wind and 2 – 7 % for biomass power projects that also reduce methane emissions, (OECD, 2004). Another analysis estimated increases of 0.5 - 2.5 % for hydro, wind and geothermal, 3 – 7 % for crop and forest residues, and 5 – 15 % or more for municipal solid waste based on a $4/ton price. In power and waste management projects, carbon revenues may provide 50 % of total revenue (Cormier, 2005).

The other three types of projects have a lower percentage of TT. In these projects, CER income composes only a margin of the IRR (CMM utilization: 7 – 27 %; CWHR: 5 – 7 %; wind power: 2 - 2.5 %) with a higher risk/uncertainty of the realization of it[11]. In these projects, foreign technology is approximately 50 – 100 % higher in cost in comparison with domestic ones (Table 1). The cost of technology takes about half or more of the total initial investment (CMM project engineers, 2009). Under such a condition, the marginal and uncertain CER income can hardly be counted on to balance the higher cost of foreign technology.

In analyzing the PDDs, all projects deploying domestic technology cited the higher cost as the hurdle preventing the deployment of the foreign technology. A typical dynamic can be seen in the case of CWHR projects. Although the Japanese technology introduced in 1998 to China was very efficient it was not further deployed until five years later due to its high cost. It was deployed by only one giant cement group, which was financially sound. It was only when much lower-priced domestic substitutes were available that large-scale deployment began.

For those CMM utilization and wind power projects that employ foreign technologies, they justify use of these technologies based on their greater efficiency. The higher cost was claimed as a hurdle that requires extra CER income to overcome. These project owners were either state-owned firms or large joint venture companies that enjoyed sound financial conditions or found it easy to get loans from the bank because of their background.

Therefore, when CER income is only marginal and firms face uncertainty, the higher cost of foreign technologies stands as an obvious financial hurdle that prevents the project owners from adopting such technologies. The lower cost domestic technologies could fill the financial gap. TT can be promoted only if other conditions are met, such as the project owners' sound financial condition. Additional factors will be discussed below.

Local technology availability and feasibility

The high percentage of TT in HFC23 and N_2O decomposition projects can also be attributed to the lack of local substitute technology. The technologies deployed in neither of the two types of projects have local substitutes (or if they exist, they are weak). This also contributes to the occurrence of TT. However, in CWHR, CMM utilization and wind power projects, there are providers of equivalent domestic technology. Although the domestic substitute technology is 30 % lower in efficiency (Domestic CWHR technology has eventually closed the efficiency gap), they are about 50 % - 100 % lower in cost, and this is appealing to financially constrained project investors, particularly the small and medium sized firms (CWHR project engineers, 2008; CMM project engineers, 2009). Local technology providers can more easily gear up to local needs. For example, in the CMM gas turbine case, Chinese Shengdong 500KW capacity gas turbines not only meet the needs of the small scale mines but also are an innovative technology adaptable to the fluctuation of CMM gas concentration levels ranging from 23 % to 35 %, which was welcomed by small and medium-sized mines (CCII Engineers, 2009).

From a statistical point of view, CMM utilization projects had a lower TT level (28.8 %) than that of wind power projects (38.2 %), which conflicts with CER income contributions to their IRR (7 – 27 % vs. 2 - 2.5 %)[12]. However, when tracing the

[11] The uncertainty of the realization of CER income will be discussed later.
[12] 1 CH_4=21 CO_2.

development of TT in the two sectors, the percentage of TT in CMM utilization projects is rising while that of the wind power sector is falling. In 2005, Chinese domestic gas turbines took 90 % of the market share of China's CMM utilization projects; it dropped sharply to 50 % in 2008. The gap has been filled by three other foreign gas turbines: Caterpillar: 30 %, Deutz: 9 % and Genbacher: 6 % (International Gas Turbine Provider, 2009). The share of foreign wind turbines in China's annual increase of capacity dropped from 77 % in 2003 to 24.4 % in 2008 (Shi, 2003 - 2008). The CER income factor clearly promoted the deployment of foreign equipment and technology in CMM utilization projects, while the CER factor in the wind power sector can hardly be said to provide any causal effects. Indeed, it is difficult to explain the even higher level of TT in the wind power sector before the CDM project started. Obviously other factors are playing a more important part such as the technology diffusion effect, the government's technology localization strategy, and finance, tariff and investment leverage, which will be discussed in the following sections.

The effect of time lag on facilitating TT in CDM projects

Efficient and simple Chinese construction license procedures allow Chinese investors to obtain a license within a short time period in contrast to the long CDM procedures. Those proposing to construct a project that also has CDM potential must undergo a series of domestic procedures to obtain a license, which have become much simplified with the issuance of the "Decision of State Council on Reforming the Investment Institution" in 2004 (State Council, 2004). The reform allows for independent investment decisions without government approval if projects qualify as "State Council-authorized." The investors need only file their projects with the local and provincial governments in order to have projects "checked" (*Bei An*[13]), which practically means approval as long as environmental regulations are met (Anhui Provincial Economic Commission officials, 2009; People's Congress, 1989, State Council, 1998; Wang, 2009). The whole procedure before construction takes 3 to 6 months. CDM application procedures are complex, lengthy and uncertain compared to the simplified Chinese domestic license application procedures. The minimum length for registration is 1 year with an average application time in China of 1.2 years while the longest process might take more than 3 years, often with rejection or even without result (Chinese CDM Consultants, 2008, 2009; China 21st Century Agenda Centre and Tsinghua University Global Environment Research Centre, 2008: 28). This approval time differential has meant that most Chinese CDM projects have begun while still waiting for CDM registration. By January 16, 2009, China's DNA had approved 1846 projects. Among them, only 450 projects (24.3 %) were registered at the EB and 105 projects (5.7 %) were issued with CERs (Fig. 2).

[13] Chinese Pinyin meaning '*keep in file*' or '*filed'*.

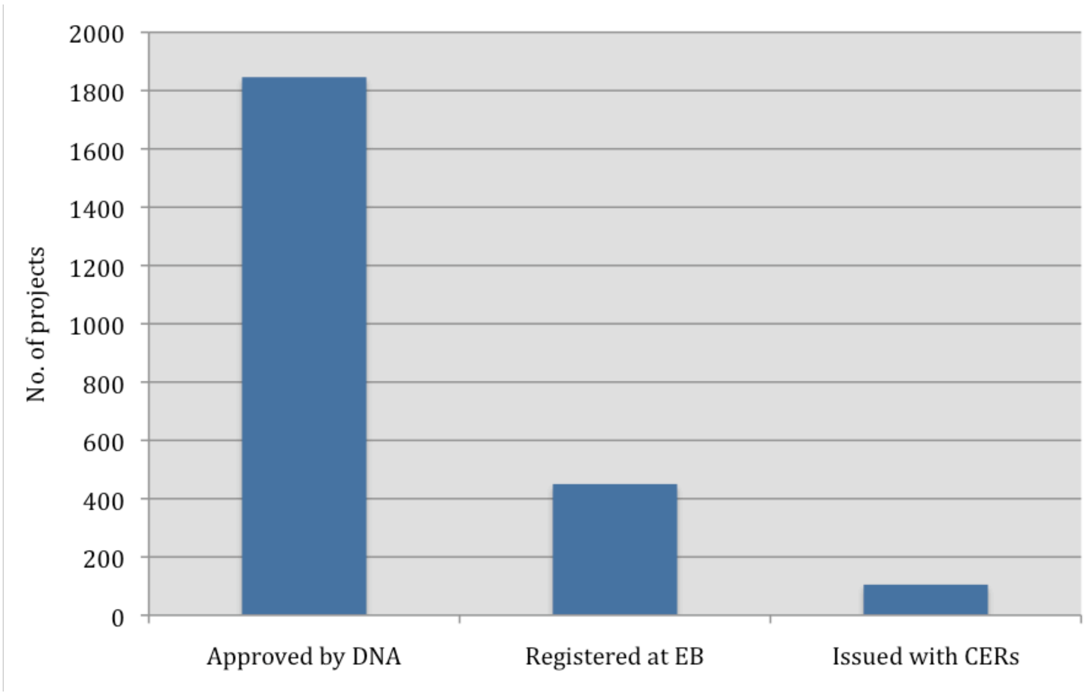

Figure 2: Number of CDM projects in China at different stages by January 16, 2009 (China CDM Database, 2009c)

Bottlenecks in China's CDM registration cycle [14]

The poor quality of PDDs from unqualified CDM project consultants (developers) prolongs the process of validation. One of the most important services the CDM consultants provide for the project owners is to produce a solid PDD with a sound methodology, and this requires an efficient team with considerable CDM expertise. However, as PDD examples can be obtained on the web and there is no strict qualification requirement for CDM consultants in China, a number of unqualified CDM consulting companies entered the business. The poorly crafted PDDs are subject to repeated revision requirements from DOEs, which means some projects did not pass validation, let alone move to the EB for registration (Chinese CDM consultants, 2008).

There are not enough Designated Operational Entity (DOE) personnel and validators to complete the validation for the increased number of DNA approved projects. Compared to the fast growing number of Chinese DNA approved CDM projects, there are only 16 DOEs operating in China. One validator can only handle 20 to 40 projects per year; the total number of validators working globally is about 75 (CEIT engineer, 2008). This is far from being enough to complete the work in China alone. DOEs also face serious brain drain challenges because CDM consultants pay a lot for experts who know how the DOE validation process works. Yet, due to profit-driven motives, DOEs sign validation contracts beyond their ability to deliver and charge a 50 % prepayment of the validation fee. They use a variety of excuses to postpone validation dates and CDM consultants face endless requests for revision. Because of the frequent changes of methodology in EB, the lengthy and time-consuming validation process can be fatal for some projects (Chinese CDM project development manager, 2009).

[14] Based on personal interviews and correspondence with CDM project consultants and international carbon traders in Beijing and Yinchuan from December, 2008 to April, 2009; Some statistics were obtained from the China CDM Information Centre and UNFCCC CDM website.

The inefficiency of the EB process also lengthens the time needed to apply and increases the uncertainty of registration. The average waiting period is from three to six months (Fig. 3). Within this period, the methodology might be revised, which means the project is reviewed again and the chance of rejection grows (UNFCCC 2009c).

In conclusion, a more qualified CDM project consultant team, a larger number of DOEs and validators and a more efficient CDM EB would lead to a more expeditious processing of CDM applications. The shortened process would enhance certainty when investors make their decisions to select either foreign or domestic technology.

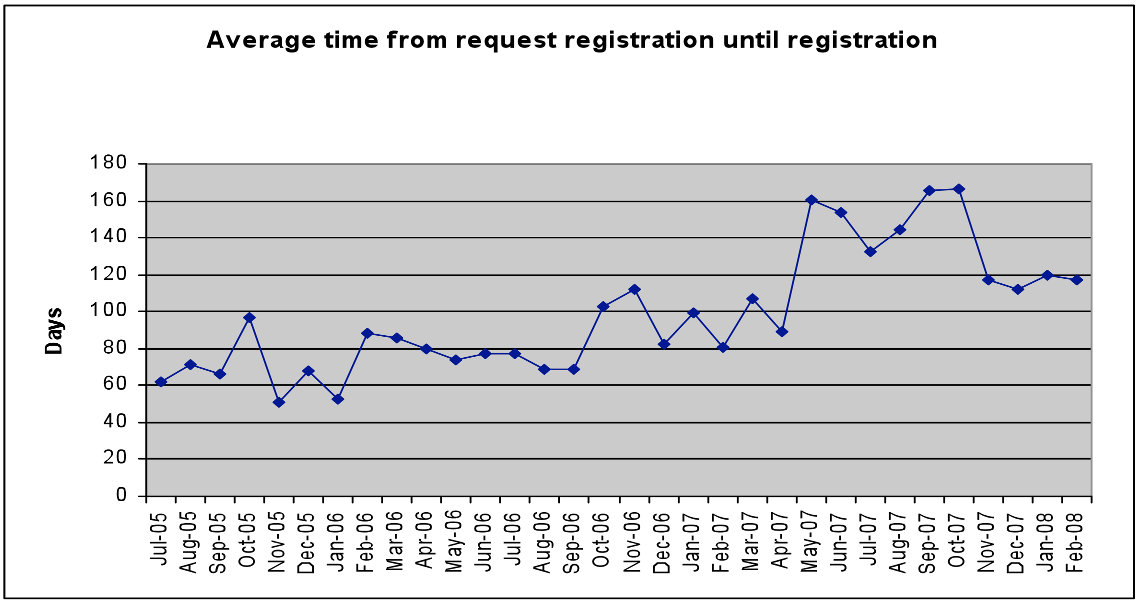

Figure 3: Waiting time at EB for registration (UNEP Risø Centre, 2009)

Interaction between technology transfer and technology diffusion in CDM projects: A successful case

China's CWHR CDM Projects

TT in the form of equipment and basic operating know-how does not naturally lead to technology diffusion. The diffusion has to be accompanied by a series other factors such as the innovation ability of the technology host, the lowering of the learning curve in cost reduction and favourable policy incentives. The CWHR TT and TD in China provide a successful case of transforming from TT to TD (Fig. 4).

There was no CWHR in China until the introduction of the first Japanese system in 1998. With the successful demonstration project in China, the Chinese host made innovations to the Japanese system and produced a system more efficient than the original Japanese technology. Presently, CWHR projects save one-third of the electricity consumed by cement production and have reduced costs by over 100 %. More than three key technology providers are also now providing similar technology to domestic customers. A set of factors including CDM incentives contributed to the process (Chao Dong Cement Factory Engineers, 2009).

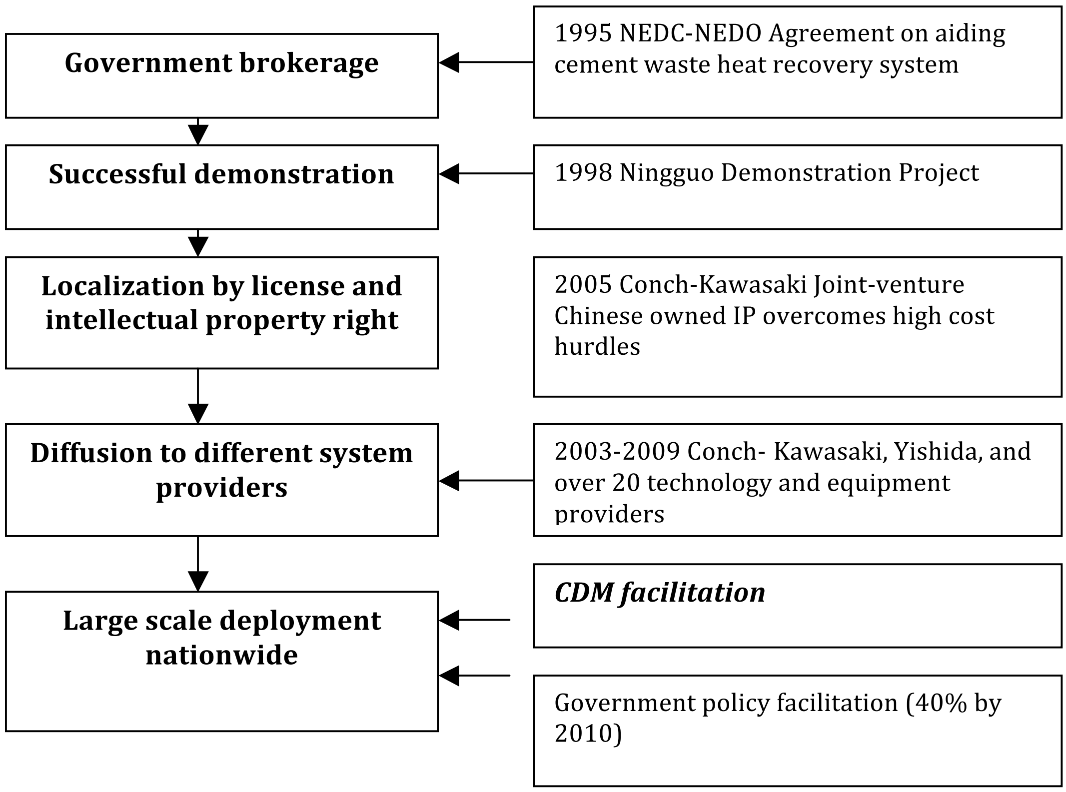

Figure 4. Model of TT to TD in cement waste heat recovery system in China (Anhui Provincial Economic Commission officials, 2009)

One factor that is important for early deployment and development is that the government serves as a broker and initiator of TT. This not only solved the asymmetrical disadvantage the host company faced in adopting novel foreign technology, but also reduced the risk of investment in the new technology to the lowest possible level by using granted foreign equipment and technology (Anhui Ningguo Cement Plant, 2002)[15]. The technology recipient has the technology potential not only to operate the system efficiently but also to independently adapt the foreign technology to local conditions and undertake incrementally minor adjustments, modifications, improvements, and optimization.

The successful demonstration of the first project eventually encouraged the company to deploy another ten lines of this technology in seven of its subsidiary companies in spite of its high cost.

CER income through CDM facilitated TT in six projects[16]. Analysis of these PDDs, suggests that the project owner excluded the choice of domestic substitute technology

[15] In 1995, the New Energy and Industrial Technology Development Organization of Japan, Chinese National Development and Planning Commission and China National Building Materials Administration jointly signed an agreement to build a Cement Waste Recovery demonstration project. With the assistance of Japanese company Kawasaki, Ningguo Cement Plant, one of the chief components of the later Conch Cement Group in Anhui Province, installed the first waste heat recovery system in China. The project began its operation in October 1998. The project was very successful both in its economic and technological benefits. The local plant adopted know-how and also leaned to improve the system by adapting it to local conditions (Anhui Ningguo Cement Plant, 2002).

[16] One of the seven projects was rejected by the CDM EB.

on efficiency grounds. The high cost of the Japanese equipment and technology was identified as the chief hurdle of the project. The 20 to 30 % higher efficiency advantage of the technology was cited as the chief argument for using Japanese technology. Considering the motivations of similar CDM projects deploying domestic technology because of high cost hurdles of foreign technology, one can assume that the better than average financial ability of the host projects was also a very important factor[17].

The special nature of the diffusion of CWHR technology is that the recipient was a large entity, which provided both the incentives and potential to localize the technology. By the end of 2008, Conch Cement had more than 59 subsidiaries and branches and two associated companies. Its total annual capacity was 70 million tons, and its total assets were 19.2 billion RMB (equivalent to around 1.7 billion GBP). For ten years, Conch Cement has been the top cement and clinker manufacturer and seller in China, as well as the largest in Asia at present. All production lines within the group are fit to install new efficient systems. With a self-sufficient market for such a technology, Conch Cement is well incentivized to obtain the production license. Thus through the joint venture business form, Conch obtained the production license from Kawasaki and transformed itself from a recipient to a domestic technology provider. The advantage of being both a technology provider and applicant allowed Conch to reduce technology costs and optimize efficiency simultaneously, which eventually contributed to its large scale of technology diffusion. By the end of 2008, the number of projects in China that deployed Conch technology had reached 62, which comprehended approximately one-third of China's market. CER income through CDM provides economic incentives in facilitating the diffusion of waste heat recovery technology. With the support of CER income ($10/t CO_2), the projects could generally increase their IRR by 5 – 7 % (Anhui Conch Cement Co. Ltd., 2007,2009).

National policy promoted the diffusion of this technology. Under the national strategic aim to reduce China's energy intensity by 20 % in its "Eleventh Five-Year Plan," promoting the deployment of the Cement Waste Heat generation system satisfies one of the government's objectives. China's NDRC issued "Some Opinions on Speeding up the Restructuring of the Cement Industry" in April 2006 in which it recommended that 40% of the existing cement production line would have to be equipped with waste heat generation systems by 2010, and the cement industry energy consumption intensity reduced by 25 % (NDRC et al., 2006a). CWHR projects also fall into one of the ten national energy conservation and efficiency categories (NDRC et al., 2006b). This stimulated the local government to urge cement companies to install such technology. In some provinces such as Anhui and Henan, the local companies even signed a "Jun Ling Zhuang" (meaning: a solemn commitment) to fulfil 100% of the target instead of 40% (Anhui Provincial Economic Commission officials, 2009).

In sum, as energy consumption absorbs half of the cost in cement production, the CWHR technology diffusion in China has led to a one-third reduction in electricity used for cement production, and thus a significant reduction of CO_2 in this sector across the country. CDM income facilitated both the TT stage and the diffusion stage. Successful diffusion by definition means that TT has become unnecessary. As the technology develops even further, with higher efficiency, lower costs and higher IRR, the additionality in the projects will gradually fade away. There will be no more such CDM projects. If that happens eventually in this sector, it will demonstrate the success of TT and CDM facilitation. This will also achieve the goal of emission reduction through not

[17] But the successful implementation of the project did not lead to large scale diffusion of the technology because the expensive equipment from Japan was beyond the financial ability of most cement plants to purchase.

only the hotly discussed sectoral approach, but also by means of more market-oriented and voluntary methods.

Conclusions and Prospects

Two key factors that affect the occurrence of TT in China's CDM projects are CER income and the availability of local substitute technologies. When CER income is high and secure, and when local technology availability is low, TT is very likely to occur. However, in the majority of CDM projects, when CER income is marginal and local technology availability is high, other factors play a more important role in deciding levels and forms of TT in CDM projects. These include the time effect (whether the expectation for future CER income is strong), the technology diffusion factor (lowering the cost hurdle), government involvement (either by its policy leverage or direct participation) and additional investors and brokers (such as international carbon traders and CDM project consultants who participate because of market incentives).

The incompatibility of the Chinese DNA efficient approval procedures with the much slower CDM validation and registration process creates a significant time lag between CER realization and project investors' decision to employ foreign technologies. This greatly constrains the effectiveness of using CER income to offset the financial hurdle in TT. China's comparative advantage (its self innovation capacity) facilitates the process of technology diffusion by lowering the cost of technology procurement. The fast diffusion of CWHR technology in China has demonstrated its great effect in GHG reductions. The Chinese government's policy creates a hospitable environment for CDM projects. The nation's prioritized forms of TT stress the localization of the manufacturing of foreign equipment and obtaining the production license and eventually independent property rights. This orientation conflicts with the interest of foreign technology providers, who favour selling their own equipment to make maximum profits. Therefore, China's strategy to localize foreign technology will eventually reduce the employment of foreign technology in CDM projects by stimulating competitive peer local technologies.

As most of the low-hanging fruit in the CDM market have been picked, international carbon traders and CDM consultants have begun to turn their eyes to the introduction of foreign technologies into Chinese CDM projects in exchange for more favourable CER contracts and more secure additionality which means a more reliable flow of CERs. Although few carbon traders and consulting companies have implemented TT in CDM projects in China, the strong economic incentive to do so, and the advantages of traders and consultants in linking international technology providers and Chinese CDM project owners, would likely make them active agents in promoting TT through CDM. CDM participants such as the EB, DOEs, carbon traders, CDM project consultants and project owners all face individual challenges in improving the efficiency of carbon emission reductions. One can hope that a more efficient CDM process will make CER income more capable of overcoming cost hurdles in TT. Stricter standards of additionality and greater competition in CDM markets will spur carbon traders and project consultants to play more active roles in assisting project owners to invest in TT to assure CER income. Both the Chinese government's priority strategy of localizing foreign technology and market allocation forces should advance the forms of equipment and operating know how to higher levels, given China's large potential for new technology deployment.

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