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Prospects for Industrial Technology Transfer in Chinese Cement Industry

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Prospects for Industrial Technology Transfer in Chinese Cement Industry

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ABSTRACT

China is the world's leading cement producer and the second largest emitter of greenhouse gases. Due to widespread use of outdated technology, energy efficiency in Chinese cement production is generally poor, despite a reduction in national energy intensity during the past two decades.

For reasons not including climate concern, a process of structural transformation of China's cement industry has been initiated through policy statements and regulatory measures. If successful, the reform will bring substantial reductions of greenhouse gas emissions, but competing objectives and other impediments will make progress slow. A future framework such as the clean development mechanism, which creates market-based incentives for foreign private actors to invest in technology transfer, may catalyse the transformation. Dual objectives of climate change mitigation and third world development could be combined.

Various barriers in China threaten to deter climate-change driven, privately funded technology transfer. Based on literature studies and on-site interviews, this paper touches upon the reasons for this situation and ways to address it. Systems of innovation, capacity building, industrial behaviour, and market change exemplify focal areas of the analysis.

Introduction

Technology transfer as an academic concept is linked to the study of technical innovations and is subject to theorising within a multitude of disciplines. In this paper, technology transfer is considered from a technical point of view in the context of international discussions on climate change, as previously treated by Forsyth (1998), Martinot, Sinton & Haddad (1997), Metz et al. (2000), and Worrell et al. (2001).

In the United Nations Framework Convention for Climate Change (the Climate Convention), technology transfer is explicitly addressed in article 4.5, which makes developed countries commit themselves to the promotion of technology transfer to developing countries as a strategy for reducing the stress on global climate patterns. In 1998, the annual conference of the parties initiated a consultative process on technology transfer.

The Kyoto Protocol is a treaty under the Climate Convention, in which developed countries make quantified commitments to limit the emissions of greenhouse gases. The protocol, which has not entered into force, contains the provision for three flexibility mechanisms. The clean development mechanism (CDM) is one of these. When in place, it will allow projects executed in the third world to generate emission reduction credits. The

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CDM has three explicit purposes: First, to assist developing countries to achieve sustainable development, second, to assist developed countries to comply with emission limitation commitments, and third, by generating funds, to assist those developing countries that are particularly vulnerable to climate change in meeting the cost of adaptation (FCCC 1999). Equity and technology transfer are both important components of the CDM.

So far, developed countries are responsible for the major portion of annual greenhouse gas emissions. Soon, however, the third world will become the dominant source. China, a developing country and home to one fifth of the entire global human population, already has the second largest national greenhouse gas emissions in the world, and is predicted to overtake the United States within twenty years (Johnston 1998).

The Chinese energy system is totally dominated by coal as a source of primary energy. In 1992, industry, responsible for 67 % of total energy use in China, consumed almost 390 Mt of coal and 530 TWh of electricity (Sinton 1996, IV 27, IV 50-51).¹ Out of these amounts, cement production, being one of the most energy intensive industrial sectors, accounted for 45 Mt and 31 TWh, respectively (Zhu 2000). Since 1992, cement production in China has increased rapidly, almost doubling from some 308 Mt to an estimated 576 Mt in 2000 (Liu 2000). China is the world's leading cement producing country, responsible today for over one third of the global output. Industrial energy intensity in China has continuously declined since the late 1970s, but it is not until the recent past few years that there has been a decrease also in the total amount of energy used (Sinton, Levine & Wang 1998).

With climate change and greenhouse gas emissions in mind, cement industry is an important sector to observe. Not only is production very energy intensive and cement itself significant especially in developing areas with large needs for infrastructural investments. In addition, cement production involves a calcination process, in which carbon dioxide is released when heated calcium carbonate is transformed into calcium oxide to form clinker. In 1996, Chinese cement production emitted 99 million tonnes of carbon, constituting almost 11 % of China's national total emissions. Half of these cement-related emissions were caused by energy use, while the rest were the result of calcination (Zhu 2000). In all, they approximately equalled the total national emissions of France.

Objective

Starting out with an assumption that, in the future, transfer of energy efficient industrial technology may be channelled through international frameworks induced by global concerns about climate change, our study set out to investigate the present situation of the Chinese cement sector. The purpose has been to shape an understanding of the sector's preparedness in practice to accept initiatives to reduce greenhouse gas emissions. Various reports on energy efficiency in Chinese cement production agree that the potential for improvements remains considerable (Liu & Wang 1994; Mohanty 1997; Price, Worrell & Phylipsen 1999; Zhu 2000). Our aim has been to explore whether and how climate-change related technology transfer could help realise these potentials, for example through the CDM,

¹ On a national average, 83 % of Chinese electricity generation in 1992 were based on fossil fuels (which, almost exclusively, means coal). The remaining 17 % were accounted for by hydroelectric generation. (Sinton 1996, II 60-61).

and the topic is problemized in this paper, which is based on the experiences from a visit to China in November 2000.

Through literature studies and a series of semi-structured interviews with representatives of relevant organisations in China, information has been collected, and our findings have been processed in an analytical framework based on theories of technology transfer. The framework comprises six factors, to which the aspect of Chinese views on climate change and technology transfer has been added. They are: macroeconomic conditions, national systems of innovation, capacity building, patterns of industrial behaviour, government-induced market change, and technical standards and codes.

Chinese Cement Industry

Since economic reforms began in 1978, Chinese cement production has boomed. From an annual output of 80 Mt in 1980, there has been a seven-fold increase in twenty years (Liu 2000; Liu & Wang 1994). Today, many domestic analysts agree, the situation has stabilised, and in the future production will grow only moderately. The massive increase up until now was realised through the establishment of the present structure of a fragmented industry, totally dominated by small-scale, low-capacity, and low-tech rural enterprises. Given the technical capacity of their equipment, and in international comparison, these enterprises often suffer from an unwarranted high use of energy, which can be explained by insufficiently trained labour and a low degree of automatization. Compared to so-called foreign advanced kilns, the average energy intensity (in kJ per kg output) of all kinds of kilns in China is considerably higher: some 23 % for precalciner kilns, and 63 % for vertical shaft kilns (Zhu 2000).

Estimates of the present number of cement kilns in China vary. In a recent report on the sector's greenhouse gas emissions the Energy Research Institute claims the number to be slightly over 9400 (Zhu 2000). Vertical shaft kilns, which have low production capacities of between 50 and 350 tonnes of clinker per day (Liu 2000), make out the great majority of these kilns, some nine out of ten. They represent almost eighty per cent of the total cement production of China. For several reasons the situation is recognised as unsatisfactory. Resource waste, inferior product quality, and poor environmental performance are obvious adverse phenomena. Consequently, planning authorities are currently implementing a framework to structurally transform the Chinese cement sector.

In accordance with central policy, cement plants that are badly managed, use outdated technology, and cause environmental disturbances are successively being forced to improve or cease operation. To enact such a policy, the State Economic and Trade Commission (SETC) publishes a black list of technologies that are explicitly banned. Since 1996, according to claims by the State Administration for Building Materials Industry (SABMI), small-scale capacity corresponding to 60 Mt per year has already been abolished, due to SETC's banning of kiln diameters less than 2.2 m. In addition, and as of the end of 2000, cement kilns with production capacities below the equivalent of 120 tonnes per day are no longer allowed. Even stricter regulations apply to new plants. As a general rule, only precalciner rotary kilns are permitted in new installations.

Dating a few years back, there exists an explicitly formulated ambition by central authorities to make the cement sector a "green industry" in China. The main meaning of this formulation, as explained by China Cement Association, is to achieve a high level of

resource efficiency. A green cement industry will not produce any solid waste products, but will contribute to the disposal of such waste from other sectors, for example through addition of fly ash and slag to clinker to form cement. Resource efficiency also applies to energy use, for which, on the enterprise level, reduced energy intensity can easily be motivated. According to SABMI statistics from 1991, the cost of energy constituted 40 % of the total production cost of cement (Liu & Wang 1994). However, despite the fact that the building materials industry as a whole is the largest industrial consumer of coal after electric power production, emission reductions are generally not included when referring to the concept of a green cement industry. Generally, only dust is recognised as a problem. SO₂ and NO_x emissions from cement production, it is claimed, cause no serious impacts and are kept below regulatory standards. SABMI officials point out that SO₂ is absorbed by the clinker, which functions as a filter for the combustion exhaust gases, and further reductions of NO_x emissions have to be addressed during plant design. CO₂ emissions are admittedly very high, but the greening of China's cement industry does not, yet, include an ambition to reduce greenhouse gas emissions.

Observations

Macroeconomic conditions. So far, investments by foreign-owned corporations in Chinese cement sector have been limited, both in capital and number of enterprises, but there is a clear interest on the part of international actors to at least be present on the market (Hilb 2000; Nicholls 2000). Leading international cement conglomerates such as Holderbank, Heidelberger Zement, and Lafarge are all represented in China. Due to large differences between the international and Chinese market situations, foreign actors are likely to remain cautious about extending their involvement, which would typically be based on a primarily long-term perspective to establish relationships and acquire experience. Foreign direct investment in the form of joint ventures is preferred to whole ownership and to other modes of market participation, such as licensing and franchising (Hilb 2000).

The single largest actor to date on China's cement market is the Chinese Anhui Conch Group, which in 1999 had a total sales volume slightly less than 5.7 Mt (Conch 2000). The company has taken the lead in a domestic consolidation trend, and the development is encouraged by central authorities. However, control over the vast majority of cement production capacity is still scattered over thousands of small, independent enterprises. Most are either state-owned or so-called township and village enterprises. State ownership is executed on many different levels of government, mostly locally and provincially, and in practise, therefore, state enterprises compete with each other on common, local markets. In the future, analysts at Tianjin Cement Industry Design and Research Institute suggest, there will probably be considerably fewer actors on the market, perhaps only some eight to ten large-scale groups, which may be both domestic and foreign. The realisation of such a scenario, however, will require a large span of time, and many problems have to be dealt with in the process (Xu 2000).

Structurally, eastern China has developed rapidly, whereas the western part of the country lags behind. Bridging this gap in development between the flourishing East and the impoverished West is presently an item of top priority on the Chinese political agenda, and one which will require infrastructural investments and local access to large quantities of

cement. Therefore, it is expected that lenience in the enforcement of cement sector transformation policy may be necessary.

National systems of innovation and technology. Apart from manufacturing enterprises, a great number of other actors also constitute parts of the Chinese cement sector. A rough overview can be given by defining categories such as authorities, branch organisations, technology institutes, management institutes, and policy institutes.

Besides a multitude of sub-state-level authorities, many state-level authorities are involved in the sector, the most important of which are SETC, and the State Development and Planning Commission (SDPC). On the ministry level, the State Environmental Protection Agency (SEPA), the Ministry of Science and Technology (MOST), and the Ministry of Foreign Trade and Economic Co-operation (MOFTEC) survey their respective areas of authority. Apart from enforcing regulations, authorities supervise the involvement of foreign actors. At present, the procedure for foreign investment approval in China follows the steps below. First, enterprises in China and abroad establish contact and agree to apply for approval. Application is made by the Chinese party to the local authorities, which, if in favour of the proposal, will forward it to the relevant central authority. Projects involving revision of industrial technology are handled by SETC, while SDPC takes responsibility for the establishment of new plants or production lines. Large projects are passed on to the State Council. After having reviewed and accepted the primary application, the foreign investor will be called upon to present a proper feasibility analysis of the project. Only upon the approval by the authority of such a document, the case will be passed on to MOFTEC, which administers the final negotiations leading up to implementation (Wu 2000).

SABMI, which used to have a sectorally administrative and co-ordinating function, has been abolished as of November 2000. Its main supervising functions have been transferred to SETC, and the role of protecting the interests of cement manufacturers, it is expected, will be shouldered by China Cement Association, which is a government-initiated branch organisation.

In the field of technology research, there are several cement industry design and research institutes that used to be controlled by SABMI. The largest one, which is located in Tianjin, has been transferred to the Enterprise Committee of the State Council. Overall technical competence is high, but diffusion appears to be poor. The Centre for Environmentally Sound Technology Transfer (CESTT), which is closely knit to the Administrative Centre for China's Agenda 21 and MOST, concerns itself with technology in a general and cross-sectoral sense, mainly addressing the needs of small and medium-sized enterprises.

In terms of enterprise management development, actors include the National Cleaner Production Centre (NCPC) and China Academy of Management Science. NCPC is currently undertaking activities to influence cement-manufacturing enterprises. Promotion of rational and efficient management practices is a strategy that may improve industrial performance in a variety of ways, including reduction of emissions.

Policy research and management, finally, are an area of some political sensitivity. Being a country in transition, it is natural that China needs to reassess and develop these tools. Under the powerful SDPC, there are two centres, belonging to the Energy Research Institute, that are involved in cement sector topics. These are Beijing Energy Efficiency Centre (BECon) on the one hand and the Centre for Energy, Environment and Climate

Change (CEEC) on the other. The Division of Energy Analysis and Economy at Qinghua University also holds high competence in this field.

In general, international co-operation and investments are encouraged in China, as long as other important priorities, such as domestic environmental standards, are not violated.

Capacity building. Capacity building relevant to the areas of climate change, technology transfer, and cement production is fragmented and takes place in many organisations. A possible forum for dissemination of information and potential discussions about branch-related topics is the Chinese Building Materials Journal, which used to be published by SABMI.

At Tianjin Cement Industry Design and Research Institute, international contacts and exchanges are part of the general activities, which include quality improvement techniques, technology and plant design, etc. There are also, however, activities on a much smaller scale, for example experiments with carbon dioxide separation, but not all of these activities are communicated to partners or research colleagues.

The CEEC has so far been working to establish an overview of the current climate performance of the Chinese cement sector. The Energy Research Institute, to which CEEC belongs, and Qinghua University are the Chinese government's two main resources for policy making in the energy field. With a heavy work-load of assignments from the authorities, there is generally little space for own initiatives to build capacity, but in co-operation with Japanese partners, CEEC commences such a project in 2001, aiming to investigate the prospects and consequences of application of the CDM in the cement industry. Qinghua University also performs studies on the CDM, and the interest in the topic extends to CESTT, which tries to promote all forms of environmentally sound technology transfer.

A prerequisite for the CDM is the ability to make satisfactory estimates of greenhouse gas emissions. Chinese competence in this field needs to be developed, and for this reason there are on-going capacity-building activities at SEPA and BECon, as well as at the National Bureau of Statistics (NBS). So far, all three organisations have been working independently with different models, and, despite limited sharing of information, it is known that their results are not mutually concordant. On this issue, NBS has had more exchange with its counterparts in the United Kingdom and Norway than with SEPA and BECon.

The international community is involved in Chinese capacity building also in other ways. In co-operation with the Energy Research Institute, the United Nations Development Programme (UNDP), and the Global Environment Facility are presently engaged in a process to better co-ordinate their efforts to remove Chinese barriers to increased energy efficiency. The overall aim is to mitigate greenhouse gas emissions. Industry is included as one out of six key areas in the framework of this process, which is driven by UNDP's Beijing office.

Patterns of industrial behaviour. Excellence and independence from one's peers are prestigious traits in China. Maybe this fact can partly explain why sharing of information about priorities, projects, and progress seems to be limited among the many actors within the cement sector. In administration, there exists a general tradition of secrecy, which makes data difficult to obtain, and internal debate or discussions hard to intercept. Also, Chinese decision-making works in a complicated environment of split responsibilities and unclear liabilities, which involves many authorities on various levels but does not provide a forum

for open consultation and control. In international industrial co-operation, a historically successful strategy has focused on gaining maximum advantage, while sacrificing a minimum of integrity by making few own commitments. Hence, after several years of international contacts, China, from a national perspective, possesses state of the art technologies in cement manufacture. However, the internal diffusion of technology remains slow.

There is in China a tendency of scepticism towards private sector capacity in terms of both financial strength and competence, whereas public agencies are more readily trusted in these respects. This may be interpreted as a reflection of the traditional social and economic structure of the People's Republic. However, it is a view that does not correspond to the established situation in Western market economies, where private interests as a whole possess the greater share of both know-how and investment capital. Due to this contextual difference, foreign private investment initiatives, unless endorsed by a public agency within a formal project framework, may encounter seemingly unwarranted difficulties in gaining support from prospective Chinese partners: authorities as well as enterprises.

In the past, whereas new cement technology has been adopted by research institutes, expansion of production capacity within the industry has mainly been founded on traditional, simple, and well-established Chinese technology. The great momentum of the expansion of the past twenty years, and the lack in rural areas of funds and technical and business-management expertise, can partly explain this development.

Government-induced market change. Market change has been a distinguishing feature of China since the country embarked upon a transitional journey towards market economy. The new, centrally dictated ambition to transform China's cement production is a consequence of the side effects of this process. Policies to phase out old technology and apply stricter regulations and standards point out the direction of the process and stimulate the demand for new and modern technology.

An important and recent government-induced change, which reshuffles the relationships between actors within the cement sector, is the decision to abolish SABMI. While the administration's responsibilities as an authority is to be taken over by SETC, it is clear that resources will be shrunk and activities reduced. For example, the ambition to maintain data collection and an up-to-standard information bank about the sector's enterprises will probably be compromised. It is hoped that in the future China Cement Association, which is regarded as a non-governmental organisation even though its management personnel are appointed by the authorities, will take over the co-ordinating and information-disseminating responsibilities of SABMI. However, although China Cement Association with some 3000 enterprise members is the largest branch organisation within the overall Building Materials Association, it needs time to expand its activities. Its present staff in Beijing numbers less than a dozen. So far, the responsibility to set up local branch associations rests with the local authorities, since there is not enough awareness among enterprises themselves that they may also make such initiatives. In the long run, it is thought that China Cement Association will evolve into a more comprehensive branch organisation. Presently, however, it cannot entirely fulfil the role as an information resource and a forum for opinion-influencing discussions among sector actors (Li 2000).

SABMI's abolishment also results in the scattering of superior responsibility for the various Chinese cement design and research institutes that it used to control. Whereas the

Tianjin institute is retained in central authority control, the rest have been transferred to authorities on other levels or transformed into “technical enterprises”.

Technical standards and codes. Codes and standards are important to reduce transaction cost. Quality standards are one example, in the absence of which, the value of different qualities may not be appreciated. This, in turn, can deter technology development and investments in new technology.

In rural China, cement quality has generally not been a prioritised property to the buyer, and there has been little incentive for the local cement producer to worry about quality aspects. However, poor or uneven quality can be a serious problem in building applications where reliability in strength is essential. In the past few years, quality control has become more and more of an issue in China, and as an example of this it can be noted that ISO 9000 is gaining ground in the cement sector. There is also a change underway to adopt international product quality standards for cement, instead of the old, domestic ones. Environmental performance and quality are starting to attract attention as well, and some cement plants are in the process of obtaining ISO 14 000 certification.

Chinese views on climate change and technology transfer. China is an active party to the Climate Convention and has declared as its policy to reduce the growth of greenhouse gas emissions. Emphasis is also put, however, on the fact that developed countries bear the main responsibility for global climate impacts so far. Therefore, these countries must provide new and additional funds to developing countries and transfer environmentally sound technologies on favourable terms (Wu et al. 1998).

In addition, many Chinese establishment representatives host a fair measure of scepticism towards the application of emission reduction credits. There exists a widespread distrust towards the concept, based on the perceived risk that developed countries will profit unfairly from climate change mitigation at the expense of third world development. Credits, it is feared, might be abused to serve as a new means for economic exploitation of less developed countries. Therefore, many find it doubtful whether technology transfer in exchange for emission reduction credits can actually fulfil the stipulated requirement: that terms be favourable to the country hosting the project.

Discussion

Technology transfer. On the whole, the notion in China of technology transfer is linked more firmly to official development assistance (ODA) than to private business. For example, SETC offers explicit suggestions for possible ODA co-operation in the cement sector and regards this option very seriously, whereas less emphasis is put on private development investments (Xie 2000). This outlook has many underlying reasons. For one thing, the governments of developed countries have committed themselves to technology transfer when signing the Climate Convention. In China, this commitment is generally interpreted in terms of ODA. Private enterprises do not enjoy the same credibility as governmental organisations, and, furthermore, the occurrence of privately funded technology transfer, it is feared, might be used by governments of developed countries as a pretext for reductions of ODA funding. There may be reason to consider, however, whether or not a too narrow view on technology transfer can in fact be detrimental to actual occurrence. Instead of competition, private

initiatives may be a complement to ODA. Due to unfavourable sentiments, such additional initiatives risk being nipped in the bud.

In 1998, foreign direct investments in low- and middle-income countries exceeded, by a factor 4.5, all the money spent annually on traditional ODA.² For China, the factor was 25 (WB 2000a, 346-49; 2000b, 314-15). This condition implies that, although technology transfer financed by public funds may still be important, the potential space for privately financed activities is also substantial. Thus, in order to better comply with the spirit of the Climate Convention, an important challenge for developed and developing countries alike would be to create incentives for private actors to engage in technology transfer activities. In a market-driven context, this means that these activities need to be made profitable. Irrespective of any disputes over how large public funds developed countries are obliged or able to spend, such measures could be encouraged by all governments committed to technology transfer as a way of addressing climate change.

In the case of Chinese cement industry, an important observation can be made that, although there is a definite demand for technology transfer, there is no doubt that much of the technical capacity and competence to bridge this need already exists within China itself. Chinese institutes for industrial design and research have had beneficial contacts with world-leading cement-equipment suppliers and developers for a long time, and indigenous capacity in this area is often well at par with international top level. Therefore, in the present situation, addressing barriers to cross-border sharing of technology is not the main concern. Rather, attention ought to be directed at examining other ways of encouraging and executing the transfer of technology needed to realise a sustainable structural reform of the sector.

Inducing technology transfer to hasten the structural transformation of Chinese cement industry, whether the technology be foreign or domestic, could have noticeable positive effects in terms of reducing global greenhouse gas emissions. Climate change being a global problem, international involvement and co-operation is necessary and ought to be encouraged.

The clean development mechanism. From a climate-oriented viewpoint, the CDM can be seen as a way to address problems caused by environmental externalities. In this light, a framework for emission reduction credit transactions may be regarded as a means for redirection of private capital and technology to the third world, allowing developing countries to pave themselves a shorter and more sustainable development path towards economic welfare. The concept of technology transfer is explicitly mentioned as one of several guiding principles of the CDM (FCCC 1999).

The prospective parties to CDM projects will quite naturally perceive the mechanism in different ways. For industry in developed countries and trans-national corporations, the CDM, when established, may be seen as a way to avoid expenses or to make money. For industry in developing countries, it can be regarded as an opportunity to attract foreign capital and obtain new technology. In China, the concept of emission reduction credits tends to be regarded with scepticism and as a potential means for foreign interests to exploit the situation in developing countries. It is necessary, of course, that potential hazards of inequity

² Naturally, the present levels and amounts of public ODA are not an undisputed issue, and many will claim that they could or should be higher. The UN recommends, as a minimum target, that 0.7 % of GDP be set aside for international development promotion. Few countries comply with this recommendation (OECD 2001).

and other unsustainable consequences are recognised and avoided. However, whereas attentiveness and justified critique are constructive tools in open and honest discussions, they cannot lead forward in an atmosphere of distrust.

If the CDM becomes an additional channel for investments to promote technology transfer in Chinese cement production, the co-operative framework for the transfer as such can hypothetically be organised either directly or indirectly. Direct technology co-operation occurs when the investor is also the source of the technology, whereas indirect co-operation occurs when a third party, for example a technically advanced domestic enterprise or institute, acts as the technology source.

Any investments, which are to be eligible for incorporation within the CDM framework, need to address a number of different conditions. Begg et al. point out that different conditions have to be prioritised in various circumstances, since trade-offs between ambitions are inevitable and evaluation “against a single objective (such as economic efficiency) is inherently flawed” (Begg, Jackson & Parkinson 2001, 19). Nevertheless, certain requirements should not be compromised. The real offset of greenhouse gas emissions is one such requirement, and the additionality of this offset is another. But, indeed, how can additionality be proven when the sector is transforming anyway? The answer to such a question, or to the problem of how to determine project baselines, is not obvious. In fact, at this stage it cannot be given, since the regulatory framework of the CDM remains to be agreed upon. Still, asking the questions is important, since these issues have to be taken into account during the design of the mechanism.

Another such question might be whether or not the CDM should be allowed at all to support foreign-financed transfer of domestic technology within a developing country. The parties to the Climate Convention have agreed that “Capacity-building activities which can most successfully help achieve and sustain effective technology transfer are those which measurably utilize and enhance existing endogenous capacities and technologies” (FCCC 2000, 9). Still, opinions on CDM application may differ for political reasons. This study, however, does not distinguish between direct and indirect technology transfer. As long as real and additional emission reductions are achieved, these are assumed to be eligible for CDM crediting.

The way forward. The hoped-for transformation of the Chinese cement industry can be described as a large-scale transfer of modern technology for energy efficient production, meant to increase the sector’s performance. As a benefit, particularly brought forward in this paper, it will substantially reduce present greenhouse gas emissions. Implementing this transformation, although urgent for many reasons, will unquestionably require a slow and long process. On the one hand, many potentially conflicting ambitions such as safeguarding rural employment and development rival for priority, on the other, barriers such as insufficient funds, poor diffusion of information, and structural inertia impede progress. In order to make a structured attempt at formulating a coherent strategy for the promotion of the process, three hypothetical main implementation paths can be suggested, none of which necessarily exclude the others. These are: 1) domestically funded change, 2) foreign-supported projects through ODA, and 3) private investments from abroad, based on the realisation of reduced greenhouse gas emissions.

Each of these strategies has its weaknesses, strengths, and prerequisites, which implies that they may be combined into a more robust whole. Most measures taken and

policies adopted so far focus on the first strategy, domestically driven action, and give little attention to foreign involvement in the sector's development. Whereas the technical capacity to implement the transformation exists within China, this strategy has a disadvantage in the fact that resources in the form of domestic funds are limited and domestic technology transfer is slow. Therefore, central Chinese authorities also encourage foreign support through ODA – technology, policy, and management being explicitly highlighted as suitable targets for model projects. The competition for available ODA funds, however, is tough between developing countries and different projects worthy of support. There are many different criteria that have to be considered by the agencies that grant ODA. Therefore, the amount of funds that may spill over onto Chinese cement sector restructuring can only be marginal.

The third path, using policy mechanisms to induce a flow of foreign private funds into the Chinese cement sector, is not generally recognised as an option. This may change, however, if and when private investors become interested in reducing greenhouse gas emissions. Today, the process following the Kyoto Protocol agreement on flexibility mechanisms, especially the CDM, is an indication that such incentives may evolve. Even though the CDM is still an immature concept, where a lot of research and negotiation is needed in order to arrive at a functional framework, it appears to hold the potential to become an important source of funding. If such prospects of emission reduction investments appeal to actors who are involved in the promotion or implementation of Chinese cement sector transformation, there is reason to make preparations at an early stage by getting involved in climate change issues. Early removal or reduction of the barriers that can already be identified may prevent future investors from being deterred.

Among the presently most important barriers in China to future climate-change mitigatory technology transfer in the cement industry, our study especially highlights the following. (I) The lack of attention on the part of Chinese authorities and industry to the connection between cement production and greenhouse gas emissions, and to the potential to substantially reduce these emissions, which is inherent in the initiated process of cement sector transformation. (II) The fact that, with regard to the concept of flexibility mechanisms, mindfulness and caution – which in themselves can be constructive – with some influential Chinese parties have turned into reluctance or even distrust. (III) The rigid and inert structure that limits information sharing and cross-sectoral open discussions in Chinese bureaucracy and decision-making. In combination these aspects may very well hinder sanctioning even of beneficial projects, which could emerge once an internationally accepted framework such as the CDM exists. The complex Chinese system of shared responsibility between different authorities on various levels increases this risk, since many institutions with different agendas and priorities are involved in the process of project approval.

As an important strategy for reduction of all of these obstacles, we suggest increased efforts for networking and information sharing. Already, many institutions in China are involved in investigations and research, which address issues of relevance to this area. However, in many cases, communication between institutions is poor. Sometimes this may be due to a tradition of secrecy or even rivalry between parties. Therefore, some tasks are being performed in parallel without mutual insight that could increase the quality of everyone's results and prevent waste of resources in the form of labour and money. To create a dynamic environment for innovations, open exchange of information rather than secrecy needs to be promoted. This applies not only to actors within China. International participation and involvement at various levels are also critical.

Summary

The present structure of the Chinese cement sector is unsustainable, mainly due to its heavy dependence on outdated technology. In response, a structural transformation process has been initiated through central policy statements and regulatory measures. The problems addressed by the authorities are principally poor energy efficiency, resource waste, inferior product quality, and excessive local emissions of dust. So far, however, the significance of the potential of this transformation process to alleviate also a share of anthropogenic greenhouse gas emissions has been largely ignored.

This paper indicates three sources of funds that may be combined to finance the process of change: domestic resources, ODA, and foreign private capital. Of these, only the first two are readily recognised and accepted in China. We therefore raise the issue of whether or not the Chinese cement sector in the future might also become an interesting arena for international investments. An important provision would be that domestically and internationally accepted climate-related policy instruments and mechanisms are developed that assign a market value to reductions of greenhouse gas emissions. The CDM, it is suggested, may evolve into such a mechanism.

The establishment of functional, institutional frameworks for the CDM will not on its own, and automatically, open the path for international involvement in the sector. Further barriers have to be removed, which will otherwise deter investors. A few, China-specific key obstacles are indicated in this paper. These are: lacking attention to the connection between reduced climate impact and improvements in cement sector performance, scepticism about the CDM as a concept on the one hand and private capital on the other, and a structural environment restraining co-operation and discussions about important ideas, policies and priorities.

Despite the possible benefits to China, present attitudes towards foreign private investments for reduction of greenhouse gas emissions tend to be inhibitive, and market actors are poorly informed about the topic. If these conditions are balanced with time, and if international climate change negotiations lead to operative frameworks for flexibility mechanisms, an important source of foreign funding may arise for Chinese cement sector development.

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