climate policy

synthesis article

Waste energy recovery CDM projects in China: status, challenges and suggestions

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The recovery potential for waste energy from major Chinese industries is significant. For example, the estimated waste energy recovery potential is 40 million tons of coal equivalent in the iron and steel industry, accounting for ~10% of the total energy use in the industry. A detailed overview is presented of existing waste energy recovery Clean Development Mechanism (CDM) projects in China. These projects have been developed predominantly in large enterprises and rarely in small or medium-sized companies. The chance of waste energy projects being reviewed or rejected by the Executive Board is slightly higher and delivery rates of certified emission reductions are generally lower than other types of CDM projects. Several major barriers that inhibit project development are identified, such as the lack of CDM awareness or development capacity among many small or medium enterprises, low internal rates of return of the projects, increasing review risk and long delays in the registration process, the varying quality of intermediary buyers, a lack of local Chinese Designated Operational Entities, and policy implementation inconsistency at different levels. Suggestions are put forward to address these problems and such critical issues as additionality are also discussed.

Keywords: China; Clean Development Mechanism (CDM); waste energy; waste gas; waste heat

Par exemple, le potentiel estimé de récupération d'énergie dans l'industrie du fer et l'acier est estime à 40 millions de tonnes d'équivalent charbon, ce qui représente environ 10% de la consommation totale d'énergie dans l'industrie. Un aperçu détaillé des projets de Mécanisme de Développement Propre (MDP) existants en récupération d'énergie en Chine est présenté. Ces projets ont pour la plupart été développés dans les grandes entreprises et rarement dans les petites ou moyennes entreprises. La possibilité de mise en revue ou de rejet des projets de récupération d'énergie par le Conseil exécutif est légèrement plus élevée et les taux de délivrance des Unités de Réduction Certifiée des Emissions sont généralement plus faibles que pour les autres types de projets MDP. Plusieurs obstacles majeurs entravant le développement de projets sont identifiés, tels que le manque de sensibilisation sur le MDP ou de capacité de développement parmi nombreuses petites ou moyennes entreprises, les faibles taux de rendement interne des projets, les risques accrus liés à la revue des projets et les longs délais d'enregistrement, la qualité variable des acheteurs intermédiaires, un manque d'entités opérationnelles désignées locales, et des incohérences dans la mise en œuvre des politiques à différents niveaux. Des suggestions sont faites pour résoudre ces problèmes et des questions cruciales telles que l'additionnalité sont également examinées.

Mots clés : chaleur perdue; Chine; effluent gazeux; énergie perdue; Mécanisme de développement propre (MDP)

1. Introduction

Improving industrial energy efficiency is a top priority for China. The country's total primary energy consumption amounted to 2850 million tons of coal equivalent (tce) in 2008, and the industrial

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http://dx.doi.org/10.1080/14693062.2011.588419 ISSN: 1469-3062 (print), 1752-7457 (online) www.tandfonline.com/tcpo
Routledge Taylor & Francis Group

sector alone used more than 70% of this total (NBS, 2009). China's industrial energy intensity in terms of energy consumption per ton of material output was between 6 and 60% higher than the world's lowest rates (Yang, 2008). This is partially due to the low recovery or utilization rate of waste energy in major energy-intensive industries in China, such as the iron and steel, non-ferrous metal, coal, construction and chemical industries (NDRC, 2004). There are, for example, 225 new suspension preheater kiln cement production lines in China with a daily output of above 2,000 tons, but only a few of them are equipped with waste-heat power-generation equipment (Wen and Zhang, 2008).

Better recovery or utilization of waste energy can substantially decrease energy consumption and greenhouse gas (GHG) emissions. China has made nationally appropriate mitigation action (NAMA) pledges to the United Nations Framework Convention on Climate Change (UNFCCC) and reaffirmed its stated intention to reduce its carbon intensity by 40–45% by 2020 from 2005 levels. One of the important NAMAs in China is to increase the effective recovery or utilization of waste energy. Among the 50 key national energy conservation technologies promoted by China's National Development and Reform Commission (NDRC), 14 are waste heat, pressure or gas utilization technologies. The coke dry quenching (CDQ) technology adopted in the iron and steel industry, for example, can reduce GHG emissions by using power generated from coke-quenching waste heat as an alternative to using the national grid or on-site power plants. Only 14 sets of CDQ units existed in China at the end of 2000, but the number had increased to 89 by the middle of 2008 (NDRC, 2008). The Clean Development Mechanism (CDM) can encourage Chinese enterprises to more actively recover or utilize waste energy and is an important instrument by which developing countries can obtain financial and technology support from developed countries and reduce GHG emissions. China is now a leader both in the total number of registered CDM projects and in the total amount of issued certified emission reductions (CERs). By way of international comparison, as of mid-September 2010, China's share of the number of registered projects is ~40% and its share of the total number of issued CERs is ~54% (UNFCCC, 2010). About 8% of registered CDM projects in China are concerned with waste energy recovery, accounting for more than half of the world total. However, there is a huge gap between how many waste energy projects can potentially be developed and how many have been developed. For example, it is estimated that less than 10% of technically recoverable waste energy in the chemical industry has been developed into CDM projects (for detailed analysis, see Sections 2.2 and 3.2).

Waste energy recovery or utilization is therefore of special importance to China. This article aims to answer the following questions. First, what is the potential for waste energy that could be further recovered or utilized in major Chinese energy-intensive industries? Second, what is the development status of waste energy CDM projects in China? Third, what are the major barriers to project development?

As far as the authors know, these questions have not yet been addressed in the literature, which has focused on either waste heat or gas utilization technology (e.g. Zhang, 1997; Lan, 2008; Jiang, 2009; Wang, 2009), Chinese CDM project development in general (Michaelowa et al., 2003; World Bank, 2004; Zhang, 2006; Teng and Zhang, 2009), or how to utilize the CDM for the deployment of renewable energies in China (Schroeder, 2009). This article aims to answer these questions by providing a detailed overview of the current development of waste energy CDM projects in China. The results of the study should be of particular interest to potential waste energy CDM stakeholders including project owners, consultants, buyers, Designated Operational Entities (DOEs) and the CDM Executive Board (EB). Moreover, the analysis is of great importance for policymakers, as it shows, from an empirical perspective, the development barriers and possible solutions to better recover or utilize waste energy using the CDM.

2. Waste energy related policies and recovery potential

2.1. Legislation and policies

Since 2004, due to concerns about energy security, environmental protection and climate change, China has adopted a series of energy conservation laws and policies, which establish mandatory energy conservation targets and outline comprehensive action plans and government subsidies for energy conservation retrofit projects. Waste energy recovery or utilization, in China, has been significantly encouraged by these laws and policies (Table 1).

Waste heat or pressure utilization projects, for example, comprise one of the top 10 key programmes in the 'Medium and Long-term Plan for Energy Conservation' (NDRC, 2004). The 'Implementation Measures of 10 Key Projects in 11th Five Year Plan (FYP)' (NDRC, 2006) states that waste heat or pressure utilization projects should be encouraged in the iron and steel, chemicals, cement, non-ferrous metals, coal, building materials, textiles and other industries. It also establishes the construction standards for these projects. The 'Revision of the Energy Conservation Law' outlines the use of favourable fiscal policies and energy-saving special funds to encourage waste heat or pressure utilization projects, and requires that grid companies provide the grid-connection to the qualified power generated from waste energy recovery projects at nationally set tariffs. According to the 'Interim Measures on Government Reward Funds on Energy Conservation Retrofit Projects', waste heat or pressure utilization projects with energy savings over 10,000 tce can receive government subsidies up to CN¥200 per tce in the Eastern Regions or CN¥250 per tce in the Western Regions (NDRC, 2007).

TABLE 1 Key waste energy-related laws and policies implemented in China since 2004

Type of policies	Energy policies	Date effective	Responsible agency
Laws	Revision of the Energy Conservation Law	October 2007	National People's Congress and NDRC
	Circular Economy Promotion Law of the People's Republic of China	August 2008	National People's Congress and NDRC
Comprehensive policies	Medium- and Long-term Plan for Energy Conservation	November 2004	NDRC
	11th Five-Year Plan (FYP)	March 2006	NDRC
	Implementation Measures of 10 Key Programs in 11th FYP	July 2006	NDRC
	The State Council Decision on Strengthening Energy Conservation	August 2006	State council
	11th Five-Year Energy Plan	April 2007	NDRC
	Comprehensive Work Plan for Energy Conservation	May 2007	State council
Sector (industry) polices	Top-1000 Energy-Consuming Enterprise Program	April 2006	NDRC
Fiscal polices	Interim Measures on Government Reward Funds on Energy Conservation Retrofit Projects	August 2007	Ministry of Finance and NDRC

2.2. Waste energy recovery potential in major industries

Based on available industrial data, an estimate is made of the waste energy recovery potential in major Chinese industries including iron and steel, chemical and cement (Table 2). A huge potential exists for waste energy that is technically recoverable. The recoverable potential of waste energy in the iron and steel industry, for example, is ~10% of the total primary energy use in the industry in 2008, converting to approximately 109 million tons of CO_2 emissions. The development potential for CDM projects may be slightly lower, because there are some very small projects that may never be developed into CDM projects given their high transaction costs.

2.2.1. Iron and steel industry

The iron and steel industry is one of the biggest energy consumers in China, accounting for ~14% of the total energy use (Song, 2007). There is a huge potential to capture waste energy that is not currently recovered in the industrial processes of coke making, sintering, iron making, steel making and steel rolling. It has been estimated that the average potential of waste energy not recovered or utilized in the industry is ~0.0807 tce per ton of steel produced (Wang et al., 2007). The production output of iron and steel in China was 500.9 million tons in 2008 (NBS, 2009). This is an estimated waste energy potential of 40 million tce and CO_2 emission reduction potential of 109 million tons based on an emission factor of 2.69 tCO_2/tce.

There are three main types of waste energy CDM projects that can be developed in the iron and steel industry: (i) waste heat recovery or utilization projects including power generation from CDQ, (ii) sinter ore, waste gas recovery or utilization projects including power generation from coke oven gas (COG), converter gas (CG), and blast furnace gas (BFG) and combined cycle power plant (CCPP); and (iii) waste pressure recovery or utilization projects such as top pressure recovery turbine (TRT). Table 3 documents the adoption status and targets of key waste energy recovery technologies in China.

2.2.2. Chemical industry

The chemical industry accounts for 10.3% of the total primary energy use in China (NBS, 2009), with major energy-intensive industrial processes including the production of ethylene, synthetic ammonia, caustic soda, calcium carbide, soda and yellow phosphorus. The waste energy projects include waste heat recovery of flue gas from natural gas-fired boilers of synthetic ammonia and sealing-type calcium carbide furnaces, waste heat utilization from soda production, waste heat power generation from sulphuric acid, and waste heat utilization from phosphoric acid. With an adoption rate of 50%, the technology of

TABLE 2 Total primary energy use and waste energy recovery potential in major Chinese industries

	Iron and steel industry	Chemical industry	Cement industry
Total energy use (million tce)	399	294	214
Waste energy recovery potential			
Energy contents (million tce)	40	>10	8
CO_2 emissions (million tons)	109	>26	18

Note: Since the total energy usage by the three industries is not directly available from NBS (2009), it is estimated by multiplying the national total in 2008 (NBS, 2009) and shares of each industry (Song, 2007; Zeng, 2006; NBS, 2009). Assumed energy content of 0.404 tce per thousands of kWh and a carbon emission factor of 0.8936 tCO_2/thousands of kWh. The potential may be underestimated, because it is only estimated based on several key waste energy recovery technologies.

TABLE 3 Deployment status and targets of key waste energy recovery technologies in China

Industry	Technologies	Adoption status before June 2008	Deployment target by end of 2010
Iron and steel	Coke dry quenching (CDQ)	30%	40–45%
	Sintering waste heat power generation	Early commercial deployment	10–20%
	Top pressure recovery turbine (TRT)	High share of wet TRT but only about 10 dry TRT units	100% (including 60% of dry TRT)
	Gas turbine combined cycle power plant (GTCC)	15 units in ten enterprises	20–30%
	Lurgi-Thyssen purifying and recovery of converter gas (LT-PR)	n/a	50%
Cement	Low-temperature waste heat power generation (LTWHPG)	8.5%	40%
Chemical	Low-temperature waste heat recovery in sulphuric acid production	2 units	73 units accounting for 71% among all large units
	Sealing-type calcium carbide furnace	n/a	30%
	Comprehensive energy conservation project of synthetic ammonia	n/a	50%
Non-ferrous metal, glass, construction, etc.	Flue-gas waste-heat recovery and power generation	n/a	Above 85% among large or medium enterprises
	Glass-furnace waste-heat power generation	n/a	12%
	Tube-dryer waste-heat recovery	Early commercial deployment	40%

Source: Adapted from NDRC (2008).

comprehensive energy conservation programmes for synthetic ammonia, for example, can reduce electricity consumption by 8 billion kWh, or 7.2 million tons of CO_2 emissions per year based on an emission factor of 0.8936 tCO_2 per thousand kWh (NDRC, 2008). With an adoption rate of 30%, the technology of sealing-type calcium carbide furnaces can reduce energy consumption by 3 million tce, or 8.0 million tons of CO_2 emissions per year (NDRC, 2008). With an adoption rate of 50% and an annual production of 17.65 million tons of soda in 2008 (NBS, 2009), the technology of the soda manufacturing process using transforming gas can reduce energy consumption by 0.64–2.25 Mtce, or save CO_2 emissions by 1.7–6.1 million tons each year (NDRC, 2008). The technical recovery potential for medium to large sulphuric acid projects is 0.5 tons of steam per ton of sulfuric acid. With an adoption rate of 71%, the waste gas recovery technology can reduce energy consumption by 2.1 million tce, or save 5.6 million tons of CO_2 emissions each year (NDRC, 2008). Altogether, the potential of CO_2 emissions reduction through waste energy recovery is about 25 million tons per year in the fields discussed above.

2.2.3. Cement industry

The cement industry is another major energy consumer in China, accounting for ~7–8% of the total primary energy consumption (Zeng, 2006). The primary energy and electricity consumption of clinker kiln per ton are respectively 23 and 29% higher than the world's leading level (Zeng, 2006). Currently, waste heat recovery projects in the cement industry predominantly use the technology of the new dry-process cement-based low temperature waste heat power generation (LTWHPG), which can save 32–40 kWh per ton of clinker kiln (NDRC, 2008). The production of new dry-process cement in China was 756 million tons in 2008, technically speaking, 97% of which can deploy the technology of LTWHPG (Kong, 2009). Assuming a technology deployment rate of 80%, 7% of power generation for its own consumption and an emission factor of 0.8936 tCO_2 per thousand kWh, a reduction of ~17.5 million tons of CO_2 emissions can be achieved in China's cement industry.

2.2.4. Other industries

There is a large waste energy recovery potential in other Chinese industries, including the non-ferrous metal, glass and textile sectors. The technology of flue-gas waste-heat recovery in the non-ferrous metal industry, for example, can reduce the energy consumption by 310 kgce per ton of copper (NDRC, 2008). With an adoption rate of 85%, the technology can recover 0.45 million tce of energy, or a reduction of 1.21 million tons of CO_2 emissions per year. The technology of glass-furnace waste-heat power generation in the glass industry can recover up to 8% of energy. With an adoption rate of 12%, the technology can reduce annual electricity consumption by 144 million kWh (NDRC, 2008), or save 0.13 million tons of CO_2 emissions.

3. Waste energy recovery CDM project activities

3.1. CDM projects by project type

The number of CDM projects in the global carbon market has increased sharply over recent years. China's share of the world's total number of registered projects is ~40% and its share of the total issued CERs is ~50%, due to larger than average project sizes (UNFCCC, 2010). As of mid-September 2010, the number of Chinese CDM projects successfully registered on the CDM EB was 949, of which 79 are waste energy projects (Table 4).

3.2. Waste energy CDM projects by industry

Waste energy CDM projects in China have mainly been developed in the cement and iron and steel industries (Table 5), which together account for ~73% of the total approved, and ~73% of the registered, projects. Compared to other industries, the cement industry has done better in waste energy CDM project development. The total number of annual expected CERs from projects approved by China's Designated National Authority (DNA) has reached 13 million tons and accounts for more than 70% of the total technical potential in the industry. However, the average project CERs in the cement industry are generally small, ranging between 30,000 and 150,000 tons.

In contrast, the average estimated annual CERs output of each project in the iron and steel industry is much larger, from 50,000 to 200,000 CERs in waste pressure power generation from TRT projects, 100,000–200,000 CERs in waste heat power generation from CDQ projects, to 300,000–2,000,000 CERs in waste gas power generation from COG and BFG projects. In terms of annual CERs, the iron and steel industry accounts for more than half of the total registered waste energy projects.

In the chemical industry, CDM projects have been mainly developed at sulphuric acid and phosphorus chemical plants. The 'Zhang Jiagang Waste Heat Recovery from Sulphuric Acid Production for Electricity Generation Project' registered at the EB, for example, has an annual potential emission reduction of 270,000 tons over 10 years. The development of low-temperature heat recovery or

TABLE 4 Chinese CDM projects approved, registered, issued and rejected by project type, as of 15 September 2010

Project types	DNA approved		EB registered		EB issued		EB rejected	
	Number	%	Number	%	Number	%	Number	%
Waste energy	413	16	79	8	26	9	20	28
Hydro	1,174	45	466	49	102	36	21	30
Wind	513	19	253	27	107	37	25	35
Biomass	243	9	52	5	10	4	1	1
Biogas	85	3	26	3	12	4	2	3
HFC, PFC & N_2O	42	2	37	4	17	6	0	0
Others	170	6	36	4	11	4	2	3
Total	2,640	100	949	100	285	100	71	100

Note: Biomass energy projects include landfill gas, biomass power generation and organic waste composting; biogas projects include coal-mine methane utilization and coal-bed methane utilization; and others include natural gas utilization, reforestation and carbide calcium residues projects.
Source: Authors' calculation according to data from UNFCCC and China DNA.

TABLE 5 Waste energy CDM projects in China by industry (CERs: thousand), as of 15 September 2010

Project types	DNA approved			EB registered		
	Number (%)	Annual CERs	Average annual CERs	Number (%)	Annual CERs	Average annual CERs
Cement	204 (49)	13,015	64	33 (41)	2,852	86
Iron and steel	98 (24)	27,639	282	25 (32)	11,654	466
Coke	43 (10)	5,861	136	4 (5)	531	133
Chemical	29 (7)	2,369	82	4 (5)	664	166
Electrical power	23 (6)	4,199	183	10 (13)	2,586	259
Others	16 (4)	1,127	70	3 (4)	310	103
Total	413	54,210	131	79	18,597	235

Note: Others include the pulp and paper, the glass, and the construction material industries.
Source: Author's calculation according to data from UNFCCC and China DNA.

utilization projects in large sulphur-burning sulphuric acid equipment has paved the way for high-efficiency energy use at sulphuric acid plants. CDM projects play a vital catalytic role here. The adoption rate of the technology would be much lower without the additional CER sales from the CDM. The total number of annual CERs of CDM projects in the chemical industry approved by China's DNA, however, accounts for less than 10% of the technical potential.

3.3. Methodologies applied in waste energy CDM projects

The approved consolidated methodology ACM0004 was the most applied methodology in registered waste energy CDM projects, but was replaced in July 2007 by the approved consolidated methodology

ACM0012 (Table 6). Compared to ACM0004, ACM0012 can be applied more widely; however, it is more complex and thus puts a higher requirement on project developers.

Waste energy project development is boosted by the application of newly approved methodologies, such as the large-scale methodologies of AM0055 and AM0066 and the small-scale methodologies of AMS-III.P and AMS-III.Q. Globally, the 18 projects that adopted the two small-scale methodologies have been successfully registered on the EB, but only three of them are in China. Except for some small and scattered oil wells, most Chinese refinery facilities accomplished waste gas recovery and utilization projects in 2006 or earlier. No CDM projects have yet been developed with the AMS-III.P methodology due to low expected CERs and relatively high development costs (Lei, 2009). There are currently four Chinese projects in the pipeline and 43 under the validation of DOEs that use the AMS-III.Q methodology (UNFCCC, 2010).

3.4. Waste energy CDM projects issued and issuance rates

As of mid-September 2010, 285 Chinese CDM projects had been issued with a total of 216 million issued CERs. China is now the largest host country for issued CERs and accounts for 50% of the total, followed by India (18%), South Korea (13%) and Brazil (10%) (UNFCCC, 2010). Issuance rates

TABLE 6 The number of registered waste energy projects by methodology, as of 15 September 2010

Methodology	Description	Status	Project number	
			World	China
ACM0004	Consolidated: waste gas and/or heat for power generation	Replaced by ACM0012 and valid from 3 March 2006 to 5 July 2007	129	59
AM0032	Large-scale: waste gas or waste heat based cogeneration system	Replaced by ACM0012 and effective from 28 July 2006 to 5 July 2007	2	1
ACM0012	Consolidated: waste energy recovery projects	Effective from 16 August 2008 onwards	40	13
AM0024	Large-scale: waste heat recovery and utilization for power generation at cement plants	Effective from 2 November 2007 onwards	11	3
AM0055	Large-scale: the recovery and utilization of waste gas in refinery facilities	Effective from 27 July 2007 onwards	0	0
AM0066	Large-scale: GHG emission reductions through waste heat utilization for pre-heating of raw materials in sponge iron manufacturing process	Effective from 5 December 2008 onwards	0	0
AMS-III.P	Small-scale: recovery and utilization of waste gas in refinery facilities	Effective from 19 October 2007 onwards	3	0
AMS-III.Q	Small-scale: waste energy recovery (gas/heat/pressure) projects	Effective from 10 October 2008 onwards	12	3
Total	–	–	197	79

Source: http://cdm.unfccc.int/.

vary considerably across different project types (Table 7). For industrial gases such as HFC, PFC and N_2O, the issuance rate is high, at an average level above 100%, surpassing the expected performance indicated in PDDs. For waste energy, the issuance rate is at an average level of 79% and varies substantially from 9% to 108% depending on the specific project.

There are several reasons why issuance rates vary both across different project types and within the same project type. First, from the perspective of the CDM project cycle, there are risks associated with monitoring and through to the issuance process that may lead to either reduced CERs issuance or delayed issuance of CERs. There is, for example, a potential mismatch between the monitoring plan in the PDDs and actual monitoring reductions. Second, the applied methodology and technology complexity, as well as unexpected market and local conditions, imply risks for CERs delivery. Waste gas produced and actual CERs generated, for example, have been reduced because of partial closure of production lines during the current financial crisis.

3.5. Rejected CDM waste energy projects

Currently, slightly more than 7% of the CDM projects are rejected by the EB even after DNA approval and DOE validation. As of mid-September 2010, there were a total of 172 rejected CDM projects, with the highest number being in China, India and Brazil (Table 8). About 28% of the rejected CDM projects in China concerned waste energy (Table 4), the remainder including 25 wind power projects, 21 hydropower projects, two natural gas cogeneration projects, two coal mine methane power generation projects and one municipal solid-waste power generation project. The rejection rate of waste energy projects is as high as 20.2%, compared to 8.9% for wind power, 4.3% for hydropower and 1.9% for biomass, respectively.

Additionality is the essential factor leading to the rejection of all 20 Chinese waste energy projects by the EB. Most of these projects used investment analysis to demonstrate project additionality. One common methodology used is benchmark analysis, which compares the project's internal rate of return (IRR) with a benchmark IRR. The EB rejected 15 projects because they failed to justify the use of higher sector or company internal benchmarks instead of the required electricity benchmark. The EB requested that the electricity benchmark be adopted because these project activities were designed for the purpose of selling electricity to the grid rather than for capture purposes. Three projects were rejected because they failed to justify some input values in the investment analysis. The remaining two projects failed to substantiate the identified technological or investment barriers.

TABLE 7 Issuance rates of major types of Chinese CDM projects, as of 15 September 2010

Project types	Number of projects		CER issued		Issuance rate		
	Registered	Issued	CER issued	% of total	Min (%)	Max (%)	Average (%)
Waste energy	79	26	8,768,637	4.1	9	108	79
Hydro	466	102	11,732,356	5.4	47	160	98
Wind	253	107	13,137,668	6.1	10	132	78
HFC, PFC and N_2O	37	17	171,810,507	79.4	95	129	120

Source: Authors' calculation according to data from UNFCCC.

TABLE 8 The number of CDM projects registered and rejected by host country, as of 15 September 2010

Host country	All pipeline		Registered		Rejected	
	Number	% of total	Number	% of total	Number	% of total
China	1,171	37	949	40	71	41
India	630	24	532	22	43	25
Brazil	210	9	178	8	21	12
Mexico	133	5	123	5	4	2
Others	672	25	591	25	33	20
Total	2,816	100	2,373	100	172	100

Data source: http://cdm.unfccc.int/.

4. Barriers to developing waste energy recovery CDM projects

4.1. Lack of project owners' capacity or interest

Large cement and steel enterprises dominate in Chinese waste energy CDM projects, and there is a high level of concentration. As the largest player in China's cement industry, Anhui Conch Cement Corporation Ltd has 23 sites that have implemented waste heat power generation projects. The total number of annual emission reductions from this corporation alone amounts to 3.1 Mt, which accounts for nearly 30% of the total CERs in the pipeline from China's cement industry. Generally, after one or two sites within a corporation have successfully developed waste energy CDM projects, others will follow. These large cement and steel enterprises have established close cooperation with domestic and international CDM stakeholders, and some have even established their own in-house departments to develop waste energy CDM projects.

Compared to these large actors, however, most Chinese small or medium enterprises have low awareness, limited knowledge and limited capacity for developing CDM projects. This institutional barrier is one explanation for the huge mismatch between CDM potential and the CDM projects developed. Technical and financial difficulties hamper project development during the entire project cycle to different degrees. Unlike the cement and steel industries, energy cost in some industries, such as the chemical industry, only accounts for a small proportion of the total production cost, so there is not much incentive for these enterprises to invest in waste energy recovery projects. Moreover, the benefits for engaging in waste energy projects are often perceived as being insufficient to overcome the risks. Unlike biogas or biomass projects, the increase in IRR with CER revenues is often insufficient to offset both the risks of projects being reviewed or rejected and the long delays of CER issuance of up to three years (Table 9).

4.2. Varying quality of intermediary buyers with increasing project risks

Under the weight of the financial downturn and amid lingering questions about the rules of post-2012 eligibility, the annual volumes of the overall CDM market declined from 1,476 $MtCO_2$ in 2008 to 1,266 in 2009. The secondary market, however, almost maintained the same volumes, and its share of the total increased from 73% in 2008 to 83% in 2009 (Kossoy and Ambrosi, 2010). (The secondary market is any further transaction initiated by intermediary buyers after the primary transaction.

TABLE 9 Contribution of CER revenues to IRR of major types of registered CDM projects in China, as of 15 September 2010

Project type	*N* = registered CDM projects	IRR without CER revenues (%)	Benchmark IRR (%)	IRR with CER revenues (%)	IRR increase due to CDM (%)
Waste energy	79	9.3	13	15.9	6.6
Biogas	26	5.7	15	30.5	24.8
Biomass	52	2.3	8	12.5	10.2
Hydro	466	6.0	8	9.4	3.4
Wind	253	6.6	8	8.6	2.0

Note: Three types of benchmark IRRs are adopted in waste energy related Chinese CDM projects, including sector benchmarks (e.g. 12% for the cement industry, 13% for the steel industry, 12% for the coking industry and 14% for the glass industry), 8% used in the electricity sector, and weighted average capital cost of the company (WACC) most likely used in the cement industry, ranging from 11.55% to 23.66%.
Source: Authors' calculation based on PPDs available at http://cdm.unfccc.int.

Intermediary buyers are funds or private investment groups who buy and resell CERs in the secondary market, acting as CER brokers, while compliance buyers, or end-users of CERs, are companies who require additional CERs to help fulfill their emission compliance requirements.)

The Chinese CDM market is dominated by intermediary buyers, mainly from Europe and Japan. The dominance of intermediary buyers is largely due to price differences between the primary and secondary market and a low-cost market entry. Owing to the complex CDM application process and the long registration time, compliance buyers normally directly buy large projects in the primary market or indirectly buy CERs from the secondary market. Typically, the price of secondary CERs is much higher than that of primary CERs due to the much reduced risk, although the price premium was smaller in 2009 than in 2008. The average price of secondary CERs, for example, was €16.6 in 2008, compared to €12.7 for primary CERs (Kossoy and Ambrosi, 2010). The entry gate into the CDM market is relatively low with low regulation and capital requirement. Any company can buy and sell CERs if it is registered in one of those Annex I countries that signed the Kyoto Protocol. When buyers sign the Emission Reduction Purchase Agreement (ERPA) with project owners, they only need to pay the project development cost, including validation fee, generally ranging between €50,000 and €100,000 depending on project complexities. The final payment for CERs is due only after they have been issued by the EB.

The participation of intermediary buyers significantly enlarges the CDM market, but at the same time increases project risks. Intermediary buyers vary substantially from each other. Some have very little industrial experience with respect to the specialized sector, low capital reserve, low credit ratings and are therefore at high risk of breaching their contract. Because waste energy CDM projects in the cement and chemical industries are normally small-sized projects (Table 5), the shares of intermediary buyers are higher than others. This might lead to a higher chance of projects being reviewed or rejected. As of mid-September 2010, 60 of a total of 71 rejected Chinese CDM projects were bought by intermediary buyers, as were 17 of the 20 rejected waste energy CDM projects.

Some intermediary buyers only act as buyers and are not responsible for project development, whereas others (with their own personnel and resources) act both as buyers and as project developers. In the latter case, to seize the market, some intermediary buyers tend to sign ERPAs with far more project owners than the handling capacity of their resources would support. They normally pick the low-hanging fruits and leave the challenging ones behind. Because project owners have already signed ERPAs, they cannot hire any new project developer or consultant. Some projects are therefore put into operation before they are registered on the EB, and so cannot claim CERs for any emission reductions achieved before the date of CDM registration.

4.3. Capacity of international DOEs and a lack of local DOEs

DOEs are key stakeholders in the CDM project cycle, as they perform a mandatory function within the project cycle and are authorized to validate, verify and certify CERs. As of September 2010, there were 48 DOEs in total. There are only two local Chinese DOEs, China Environmental United Certification Center Co., Ltd and China Quality Certification Center, both of which were approved in early 2009. Validation services in China are currently dominated by a small number of international DOEs with the top two DOEs, the Norway-based Det Norske Veritasdue (DNV) and the Germany-based TÜV SÜD Industries Service GmbH, accounting for 77% of all Chinese registered CDM projects. As of mid-September 2010, only two projects had been validated by local Chinese DOEs, with two more requesting registration. With a growing project pipeline, the demand for DOE services is increasing, resulting in longer project approval timelines and a long queue of projects waiting to be validated, causing frustration for project owners, developers and investors. As of mid-September 2010, for example, there were only 949 Chinese projects registered on the EB, compared to 2640 projects approved by China's DNA. The lack of local Chinese DOEs is a major concern, particularly for the development of waste energy projects, which involve a complex mix of Chinese specific policies and rules.

The DOE accreditation process has been streamlined since March 2009, but this streamlining is insufficient to get more Chinese DOEs. One significant barrier is a brain drain from Chinese local DOEs to international buyers. It takes one or two years for DOEs to train qualified professionals, but they often leave their current jobs after two or three years and accept much better offers from international buyers. A common career path for Chinese CDM professionals is to jump from local Chinese consulting companies to local DOEs and then to international buyers (with continually increasing salaries).

4.4. Inconsistent policies and implementation

Potential CDM project activities can cut across many different sectors and involve several different types of stakeholders. To send a consistent message to potential project owners and investors, it is important that there is a clear and consistent policy regarding CDM projects of a given type. Developing a consistent policy requires good communication not only among the different actors, but also among the various levels of government. Any CDM-related policy inconsistency could potentially become a major barrier to project development. Although waste heat or pressure projects are encouraged but not required by the central government, provincial and local governments have a different interpretation of laws and policies. Some local governments such as Qu County in Shandong Province have a mandatory requirement 'in principal' for implementing waste energy recovery projects in certain industries, but most other areas do not. It is barely possible to get permission from these local governments to add a new cement production line without a matched waste heat power generation unit. National and local policies that do not have a legally binding effect can be ignored during the additionality judgement, but this may lead to potential registration trouble in the near future. For example, the EB rejected the approval of eight proposed Chinese CDM wind power projects due to the lack of a clear guidance on the E+/E− issue. E+ refers to policies which give comparative advantage to more emissions intensive technologies or fuels. E− refers to policies which give comparative advantage to less emissions intensive technologies or fuels (UNFCCC, 2010).

Inconsistency between policies and their implementation could also become a barrier to CDM project development. For instance, the 'Implementation Measures of 10 Key Projects in 11th FYP' requires grid enterprises to 'provide the grid-connection service' to the power generation from waste energy recovery projects. The grid-connection regulations, however, are not always effectively or consistently enforced, because Chinese grid companies create many restrictions to discourage and delay connection, or even charge a connection fee, because of concerns about the small capacity and low stability of the power generated from such projects (Lei, 2009).

5. Suggestions for developing waste energy CDM projects

5.1. Raising project owners' awareness and strengthening their capacities

Capacity building for project owners is important to the development of CDM projects. For waste energy projects, it is particularly critical to strengthen the CDM-specific capacities of small or medium-sized companies. An information-sharing platform that is active within an industry as well as among different industrial sectors should be built to allow the easy exchange of information, including both industry-specific knowledge and experience on CDM project development. These platforms could be built by industrial associations, non-government organizations (NGOs) or CDM service centres. There are currently, for example, about 30 provincial CDM centres in China established with local governmental support and supported, to various degrees, by foreign agencies and international organizations. These centres have the potential to be valuable players in raising owners' CDM awareness and training them in CDM regulations, procedures, project management and monitoring. Meanwhile, NGOs could encourage enterprises in various ways to invest in waste energy recovery projects for the sake of the enterprises' own social responsibility.

Owners' capacity-building can also be strengthened with effective cooperation with other stakeholders such as buyers, project developers and energy service companies. Compared to buyers, Chinese project owners, especially smaller ones, are usually at a disadvantage in ERPA negotiations. Consultants, in particular, are frequently contracted by buyers to ensure the smooth implementation of the project. Owners should be more involved with project development and take more of the responsibilities from buyers that would normally fall on the owners.

It is also critical for owners to cooperate with professional CDM project developers. There are currently about 300 international and domestic project developers in China, with a high concentration of larger developers. There are two types of relationship with developers that most project owners should avoid: the first is to have no relationship at all, when owners are fully satisfied with the in-house development capability of their own technical staff, financial staff and lawyers; the second is to transfer to project developers full control of issues including ERPA negotiation, project registration and even communication with the EB.

Small or medium-sized enterprises could also cooperate with energy service companies (ESCOs). On the one hand, owners can obtain technological, management and monitoring support from ESCOs; on the other hand, ESCOs can help owners attract more potential buyers and reduce project risks by packaging small-sized projects into large ones.

5.2. Creating a credit rating system for international buyers

Project risks can be reduced if buyers are experienced and creditable. Because the CDM market in China, particularly waste energy projects, is dominated by international intermediary buyers, it would be beneficial to the market if there were a credit rating system for all major international buyers based on, among other factors, buyers' capital reserve, professional staff, experience in the carbon market and risk tolerance. Buyer rating is now provided in English by such information providers as Point Carbon teaming up with Standards & Poor's or Ideacarbon, but due to the language barrier it is not available to most Chinese project owners. It would therefore be extremely helpful to build a credit rating system for international buyers, which is regularly updated and readily available in Chinese.

In addition, Chinese project owners should seek help from independent law firms to protect their own rights in ERPA negotiations, because the ERPA is based on the English common law system, which is different from the civil law system adopted in China. Moreover, international buyers in most cases have absolute control over the rules of ERPAs.

5.3. Encouraging the growth of local Chinese DOEs

As discussed above, the lack of DOEs is a major concern for all CDM stakeholders, and the lack of local Chinese DOEs is of particular concern for certain Chinese CDM projects such as waste energy. To encourage the growth of local Chinese DOEs, the Chinese government, particularly China's DNA, should establish favourable policies to attract more DOE applicants with, for example, a special tax exemption or deduction on application-related expenses. NGOs, CDM service centres and related government agencies such as the CDM Fund Management Centre, should regularly offer free training and consulting services on DOE application. Development priority could be given to those who are already specialized in certification. The only two local Chinese DOEs recently approved, for example, are both official certification centres. Qualified validators are indispensable for the growth of local Chinese DOEs. Half of the success is to build a large pool of qualified professionals through pre-job education and on-job trainings. The other half is to retain these professionals. This could be done in three ways. First, compensation packages offered by local Chinese DOEs should be comparable to those of their international peers. Second, those employees who work longer should be rewarded with more generous performance bonuses and more vacation days. Third, intrinsic rewards should be offered such as better career development opportunities and a cohesive corporate culture.

5.4. Making policies and implementation consistent

To mitigate climate change and, more importantly, to safeguard energy security, the Chinese government (at national, regional and local levels) is making efforts to establish favourable policies to encourage energy saving while fostering the development of renewable energy. However, some policies or rules are inconsistent across levels (e.g. the mandatory requirement on waste energy recovery in the cement industry discussed in Section 4.4). China's DNA, CDM Project Management Centre or CDM Fund Management Centre should design a feedback and review system to regularly check for any policy inconsistencies. Local CDM service centres, industrial associations and project developers could act as core members of the feedback system. China's DNA should regularly check whether there is any emerging Chinese policy or rule affecting project additionality and, most importantly, work with the EB on formulating clear guidance on E+/E− policies. One likely solution for the E+/E− issue is to use a positive-type list approach for new renewable energy technologies, which are verified to be significantly more expensive than conventional power for many years (e.g. over four years), such as wind, solar, geothermal, wave and tidal energy, without the need for an additionality assessment.

Favourable policies and measures should be considered not only applicable to the enterprises that carry out waste energy recovery projects, but also to the stakeholders who may cooperate with them to make sure the policies and measures are implemented as expected. For example, in the case of the requirement to 'provide the grid connection' to power generation from waste energy recovery projects (Section 4.4), favourable policies such as a tax deduction on expenses related to the special 'connection services' should also be granted to the grid companies.

6. Conclusions

Industrial energy intensities in China are significantly higher than the world's lowest rates, and could be significantly improved by more effective utilization of waste energy in major energy-intensive industries. China has made NAMAs pledges under the Copenhagen Accord and has reaffirmed its stated intention to reduce its carbon intensity by 40–45% by 2020 from 2005 levels. The further scale-up of key waste energy recovery technologies could be implemented as a NAMA in China.

The CDM could encourage Chinese enterprises to invest in waste energy recovery projects. China is now a leader in waste energy-related CDM project implementation. However, a number of problems with the current development of waste energy CDM projects in China have been uncovered. In the chemical industry, for example, waste energy projects have mostly been developed in large enterprises and rarely in small or medium-sized companies. Compared to other projects, the chance of waste energy projects being reviewed and rejected is relatively higher, and delivery rates of CERs are generally lower.

Several major barriers hamper the further development of waste energy CDM projects in China. First, small or medium-sized enterprises usually lack CDM awareness and project development capacities, and waste energy recovery projects are often not attractive enough to large companies because of their much smaller revenue compared to the core business, lower IRR compared to other CDM project types such as N_2O and biogas, higher risks of being reviewed and rejected, and longer validation, registering and issuing times. Second, project risks increase with the varying quality of intermediary buyers. Third, the capacity bottleneck of local Chinese DOEs is a huge concern, particularly for waste energy CDM project development, which involves certain Chinese-specific policies and rules. Finally, policy inconsistency across different levels of governments has potentially negative impacts on CDM project development in China.

Several suggestions are offered to improve the development of waste energy CDM projects in China, some of which are applicable to the overall CDM market: the development of an information-sharing platform to raise project owners' CDM awareness and to strengthen their development capacities; enhanced cooperation between owners and other stakeholders; a readily available credit rating system for buyers; favourable policies to encourage more DOE applications; government-supported training programmes and consulting services on DOE applications; a feedback and review system to check any policy inconsistency; and favourable bilateral policies applicable both to owners and the stakeholders who cooperate with them.

Several issues that are important, both for waste energy CDM projects in China and for the general CDM market, and that have not been analysed in detail in this article, are worth further discussion. One critical problem is additionality. The registration practice of the EB with regard to additionality determination has changed substantially over time, and the additionality test has become increasingly stringent, leading to a rapid rise in both requests for reviews and rejections (Michaelowa, 2009a). Many projects, including those registered, are questioned about their true additionality. Largely triggered by the controversy of Chinese wind power projects, IRR-based additionality is suspected to be somewhat incompatible with non-market power sectors and dependent in most developing countries on domestic regulatory decisions (He and Morse, 2010). Meanwhile, a major concern shared by project owners, developers and buyers is the complex and stringent methodologies used to judge project additionality. Some also argue that the additionality requirement should be more flexible for those projects with small emission reductions but with huge benefits to sustainable development in developing countries.

The EB did not provide clear E+/E− guidance at its recent 53rd meeting, but expects the validating DOEs to assess the suitability of the energy tariffs. The CDM will have to be modified and some of its elements reformed if it is continued after the Kyoto Protocol. This can be addressed by either incremental reforms like the consolidated additionality tool proposed by the WWF (formerly the World Wildlife Fund), replacing project-specific additionality testing for certain project types with benchmarks and default discount factors, or introducing a programmatic CDM or a sectoral CDM (Michaelowa, 2009b). However, there is no magic solution for the additionality conundrum. In determining additionality, particularly any new E+/E− policy, the bigger picture if necessary should be taken into account regarding the potential negative impact of possible decisions on investment in low carbon technologies in non-Annex I countries, rather than just focusing on ensuring the additionality of individual projects.

The varying quality of consultants is another barrier to the CDM market, as they take the main responsibility for the development of CDM projects. Some CDM projects are rejected mainly because of the poor quality of PDDs. Consultants are more likely to pick up those projects that can be easily developed with mature methodologies and that are successfully registered with less risk, and leave behind others that are more challenging but of higher environmental benefits. Consultants also lack incentives to develop new methodologies, which is more resource-demanding than PDD writing.

Meanwhile, concerns have been constantly raised over the delay in registration, the increase in review requests by the EB, and the unpredictability in EB's decision-making. The number of average days from requests until registration, for example, has been continuously increasing to almost 200 days even before the rush of renewable energy projects in August 2008 (UNEP, 2010). The EB is facing the ongoing challenges of speeding up the completeness check process, increasing transparency and consistency of its decision-making, and refraining from retroactive application of its decisions.

The uncertainties over a post-Kyoto regime are the main concern in the development of CDM projects. The 2009 UN Climate Change Conference held in Copenhagen stated that the flexible mechanisms, including the CDM under the Kyoto Protocol, should continue in the post-2012 period and proposed plans to streamline the CDM. Nevertheless, there are still many uncertainties concerning the future carbon market that stifle CDM development enthusiasm, such as the EU's position on CDM in the future EU ETS. The limitation of the use of CDM credits is used as a 'threat' to push the major developing countries to make commitments under the post-2012 climate regime. This may lead not only to the reduction of direct CDM transactions in developing countries, but also to the reduction of indirect leverage capital investment in developing countries for clean development.

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