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CDM potential in the power-generation and energy-intensive industries of China

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1. Introduction

China is one of the most promising countries for CDM (clean development mechanism) projects. Whilst this is true in terms of physical potential, of greater significance is the economic potential of CDM projects. In this article, I develop methodologies for estimating both the physical and economic potential of CDM activities in China and apply them to power generation and other energy-intensive sectors.

This study adopts a thorough application of a bottom-up approach based on actual data collected from Tsinghua University and several power plants in China, and data from feasibility studies of Japanese companies sponsored by NEDO (New Energy and Industrial Technology Development Organization, Japan). The article also provides useful tools for estimating CDM economic potentials by sectors/technologies, which are applicable not only at the current CER (certified emission reduction) price, but also for any other possible CER prices.

Section 2 illustrates a methodology for exploring physical reduction potentials and applies this methodology to different energy-intensive sectors. The results show a physical (annual) reduction potential of 127 Mt-CO_2 in total. Section 3 presents a methodology for calculating the CO_2 abatement cost. Section 4 calculates transaction cost, yielding an estimate of approximately $350,000 per project. Section 5 examines the economic potential of CDM projects in China, taking into account current CER market price. The economic (annual) reduction potentials obtained are 15 Mt-CO_2 (far smaller than the physical potential). Section 6 explores other promising areas for CDM. The economic potential of CDM in China is shown to increase when CDM activities in 'greenfield' and landfill gas recovery are taken into account. Finally, I present various policy recommendations.

2. Methodology for calculating physical CDM potential in China and its application

With limited data availability in China, it would be worthwhile to develop a methodology which will cost-effectively calculate the credible CDM potentials in power generation and other energy-intensive sectors. CDM projects in these sectors can contribute toward reducing not only GHGs (greenhouse

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gases) but also air pollutant emissions. Undoubtedly, those projects with such ancillary benefits will be most welcomed by the Chinese government.

2.1. Power-generation sector

Based on the fact that almost 90% of China's thermal power plants are coal-fired, it is reasonable to assume that fuel switching from coal to natural gas would be the most effective CDM. However, limited access to gas pipelines, as well as the price difference between natural gas and coal, prevent this from happening throughout China. Hence, improving the efficiency of coal-fired power units is assumed to be the focus of CDM activities. The review, however, explores the feasibility of fuel-switching projects for large units located less than 10 km from existing or planned gas pipelines.

The essential features of the methodology proposed here are: (a) to focus on a particular area (by province) and collect basic data on all the power units in that area; (b) to estimate baseline emissions in the area by utilizing such basic data; (c) to select model power plants of different sizes in the area and to collect detailed information about them; (d) to use this data to calculate the efficiency improvement ratios of CDM activities for each size of model unit (e.g., 50 MW, 100 MW); and (e) to apply these ratios to all respective units of each size throughout China.

After consultation with professors at Tsinghua University, the Northern China area (three provinces comprising Hebei, Shanxi, and the Western part of Inner Mongolia) was selected as a model area because, firstly, the thermal efficiencies of these provinces (35%, 33%, and 34%, respectively) were close to the average for the whole of China (34.4% as of 2001) and, secondly, accurate data were available through the Tsinghua University network.

The basic data (such as the number of units and their capacities (MW), annual operating hours at rated load equivalent, years of operation, the carbon intensities of coal and thermal efficiencies) of all coal-fired units in the area were collected. There were 108 units with a total capacity of 17,620 MW. The data were classified by unit capacity, and the starting year of operation (Table 1).

Table 1. Power generation in northern China: number of units and capacities classified by the starting year of operation (as of the end of 2000)

Year	1960s		1970s		1980s		1990s		2000		Total	
Unit capacity	Unit	Total capacity (MW)	Unit	Total capacity (MW)	Unit	Total capacity (MW)	Unit	Total capacity (MW)	Unit	Total capacity (MW)	Unit	Total capacity (MW)
50 MW	7	350	13	650	1	50	5	250	–	–	26	1,300
100 MW	–	–	8	800	10	1,000	7	700	3	300	28	2,800
200 MW	–	–	3	600	15	3,000	12	2,400	–	–	30	6,000
300–350 MW	–	–	–	–	–	–	22	6,820	2	700	24	7,520
Total	7	350	24	2,050	26	4,050	46	10,170	5	1,000	108	17,620

The collected data clearly show that the efficiency of each unit would depend on its age and capacity. The older and the smaller the unit is, the less efficient it would become. For instance, the average thermal efficiency of 50-MW units that started operation in 1963–1972 was 31.3%, whereas that of 300-MW units that started operation during 1991–1992 was 39.1%. These numbers reflect improvements in technology as well as the decline in performance due to aging. On the other hand, most Chinese power plants have a standardized capacity and design for each size category, so that the efficiencies do not differ greatly between new and old (except for the lowering of efficiency due to aging) as long as they are in the same category (e.g., 50 MW, 100 MW, etc.). In this sense, it is quite relevant to classify units by the categories of standardized capacities.

Another point is that large power plants with a capacity of 300 MW and upward are equipped with state-of-the-art technologies and so provide fewer opportunities for energy efficiency improvements except in the case of fuel-switching projects with gas and steam turbine combined cycles. Therefore, those units with a capacity of less than 300 MW were selected as CDM candidates for efficiency improvement projects (84 units with a total capacity of 10,100 MW in northern China). For these units it is assumed that coal will be used continuously. The units with capacities of 300 MW and more (but less than 500 MW) were selected as candidates for fuel-switching CDM projects, provided that they were located within 10 km of existing or planned gas pipelines (16 units with a total capacity of 5,013 MW).

The next stage was to select the types of CDM projects for each classified size of unit capacity. For those with capacities less than 300 MW, the question was whether to scrap and rebuild existing units into larger units (S&B) or to simply modify them. In case of 50-MW units, S&B could be a reasonable option because of their inefficiency and aging. For 100–200-MW units with average efficiency, modification would be a sensible choice. As already stated, the best choice for larger capacity units was the fuel-switching option. These decisions were made on the basis of intensive discussions with an experienced engineer who had actually designed many of the power plants in China.

Based on the available data and in accordance with the methodologies listed in Figure 1, baseline emissions per unit of electricity generated in northern China were calculated. In this study, the calculation

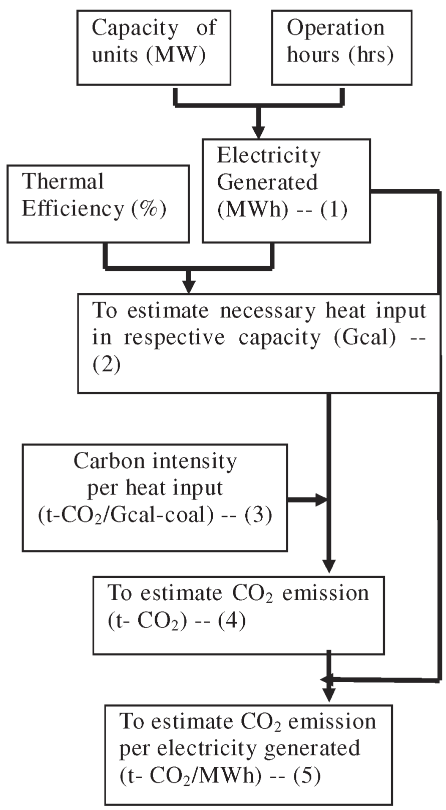

Figure 1. Methodology of calculation of baseline emission in North China.

of ‘existing actual emissions’ was done using one of the three baseline methodologies set out in the Marrakech Accord (FCCC/CP/2001/L.24/Add.2). The baseline methodologies are not discussed in detail in this review; however, due to data availability, it would have proved difficult to apply the other two methodologies. The data were compiled to provide emissions per unit of electricity generated for each of the 50-MW, 100-MW, 200-MW, and 300-MW capacity categories. Assuming that the values obtained here for the respective units in northern China would be similar to those in the same capacity categories throughout China, and the data on the number of existing units classified by unit capacities in China were available, the baseline emissions of each capacity category in the whole of China were obtained.

Next, the model plants/units were selected for further study, as shown in Table 2 (among them, a model plant for the 50-MW unit was a cogeneration plant, but as this is quite common, especially for small units, there is a rationale to select a cogeneration unit as a model). The selection criteria included the starting year of operation (in order to include both old and new plants), data availability, and the reliability of the data provided. Again, thanks to the cooperation of staff at Tsinghua University, detailed data were collected on the model units, including number of generators per plant and their unit capacities, power generated per year, heat generated per year, annual heat supply, annual operating hours, annual coal consumption, chemical composition and calorific values of coal used, gross efficiency of power plant, and other major specifications, as well as maintenance costs, fuel prices, electricity and heat prices etc. Several site visits, discussions with the staff of Chinese model plants, and the large amount of correspondence that followed certainly increased the accuracy and credibility of this study even further.

Table 2. Types of CDM option and model units

Type of CDM option	Unit capacity	Model plant
Type 1 ‘Scrap & build’ option	50 MW	Taiyuan No.2 Electric and Thermal Power Station, Shanxi Province Number of units: 50 MW × 4 units Year operation started: 1963–1972
Type 2 Modification option	100 MW	Haibowan Electric Power Station, Inner Mongolia Number of units: 100 MW × 2 units Year operation started: 1994
	200 MW	Fengzhen Electric Power Station, Inner Mongolia Number of units: 200 MW × 6 units Year operation started: 1989–1995
Type 3 Fuel-switching option (combined cycle)	300 MW	Taiyi Electric Power Station, Shanxi Province Number of units: 300 MW × 2 units Year operation started: 1991–1992

By using the detailed data on model units, the energy-saving ratios due to efficiency improvements for each type of CDM activity (types 1–3 in Table 2) were obtained (figures are shown in Table 3), on the assumption that the model units would apply advanced technologies available commercially in Japan. Then, the annual emission reduction potentials in China were calculated by multiplying the ratios (for example, 30.2% for the type 1 ‘scrap and build’ option for a 50-MW unit) with the baseline emissions of each unit capacity category (50-MW, 100-MW, 200-MW, and 300-MW). For the fuel-switching option, the difference of carbon intensity between coal and natural gas was taken into account.

Table 3. Energy saving ratios due to efficiency improvements by CDM activities

	50 MW (Scrap & build)	100 MW (Modification)	200 MW (Modification)	300 MW (Fuel-switching)
Improved efficiency (boiler and turbine)	30.2%	2.9%	3.1%	24.5%

The outcome is shown in Table 4. Total CDM potential in the power-generation sector in China was around 100 Mt-CO_2, of which fuel-switching projects had the biggest share. There are two points to be noted here. Firstly, the obtained figures indicated the 'physical' CDM potential without considering cost factors. Secondly, all the above CDM reduction potentials were calculated on the basis of three options (S&B, modification, and fuel switching). This means that no 'greenfield projects' were involved. In this article, a 'greenfield project' means a 'planned' (not already existing) plant subjected to CDM activities. The potentials for such projects will be discussed in Section 6.

Table 4. Summary of CO_2 emission reduction potentials in China (power-generation sector, unit 1,000 t)

	50 MW Scrap & build	100 MW Modification	200 MW Modification	300 MW Fuel-switching	Total
Total capacity of the targeted units (MW)	17,270	35,260	37,080	18,400	108,010
CO_2 emission reduction (1,000 t/year)	35,580	8,990	9,230	45,550	99,350

2.2. Other energy-intensive sectors

Other energy-intensive sectors, such as the iron and steel, paper, cement, chemical and petrochemical industries, may provide considerable CDM potentials, if every physically possible technology is to be adopted. However, the high costs make it seemingly impractical to introduce some of these technologies. In order to find a cost-effective way to develop methodologies for CDM, experts in the respective industries in Japan were invited to express their views on, first of all, plausible and cost-effective technologies to be adopted into CDM projects. After intensive discussions, and taking into account their Chinese counterparts' interests, several candidate technologies were selected for further study.

For example, in the iron and steel industry sector, which is the second largest CO_2 emitter in China after the power-generation sector, two technologies – CDQ (coke dry quenching) and TRT (Top pressure recovery turbine) – were chosen from 11 potential energy-efficiency improvement technologies as the most suitable for CDM. These two technologies are designed to utilize waste heat effectively. One of several reasons for selecting these technologies was that, while Japan had the CDQ and TRT equipment installation ratios at 90% and 100%, respectively in 2002, both ratios remained less than 50% in China as of 2000. This means that there will be a larger CDM potential in this respect.

The next step was to collect information about their installation situation at every facility in China. If a facility was already equipped with either of these technologies, it was excluded from the candidate sites. In this way, only those iron and steel plants with a yearly production capacity of more than 1 Mt, which had not already installed CDQ equipment, were selected as candidates.

Unlike the power-generation sector, data were not provided by China for these industry sectors until at the very last stage of this study; however, some data on the Chinese situation were collected from the literature (Li, S. Wang, Z., 1999; Price, L., Sinton, J., Worrell, E., Phylipsen, D., Xiulian, H., Ji, L., 2002; Shimomura, Y., 2000; Tunnah, B., Shumao, W., Feng, L., 1994), various feasibility study reports of NEDO (NEDO, 2000a, 2000d, 2001b, 2001c, 2002, 2003) and also through interviews with Japanese industry experts. In the end, one AIJ (activities implemented jointly) project registered at the Secretariat of UNFCCC was chosen as a model project for CDQ because of its data reliability. According to the project report, the annual processing capacity of the coke oven subjected to CDQ installation was 450,000 t-coke and an annual CO_2 emission reduction from the baseline was calculated as 68,265 t-CO_2.[1] Therefore the CO_2 reduction ratio of the model facility was 0.15 t-CO_2/t-coke (68,265/450,000).

From this, the physical reduction potentials of CDM-CDQ in the whole of China were calculated using the existing emission baseline methodology. As explained above, only those steelworks with an annual production capacity of more than 1 Mt that had not yet installed CDQ were selected as candidate factories. According to Tozai Boeki Tsushinnsha (2001), the total processing volume of coke at the candidate steelworks was estimated as 38,706,000 t/year. However, in view of the fact that 18 CDQ systems have already been installed, the potential capacity was calculated as 26,471,032 (t-coke/year). Applying the model equipment figure (0.15 t-CO_2/t-coke), the total CO_2 physical reduction potential in China from the introduction of CDQ was calculated as 3,970,655 t-CO_2/year.

Using the same concept and methodology, the CDM potential from the introduction of TRT technology to 26 large candidate plants in China (with a volume of 1,000 m^3 and more) was calculated as 978,112 t-CO_2/year.

For the remaining energy-intensive sectors (the paper, cement, oil refinery, chemical and petrochemical industries), reduction potentials were calculated using the same concepts, i.e. selecting candidate technologies and model plants, calculating the reduction potentials of model plants, and applying the results to large facilities capable of adopting new technologies, while relying on information from the literature (Hijiya, N., 1996; Liu, F., Ross, M., Wang, S., 1995) and feasibility studies by NEDO (NEDO 1999a, 2000a, 2000b, 2000c, 2001a, 2001b, 2001c, 2001d, 2002, 2003).

Total CDM physical potentials in power generation and other energy-intensive sectors in China were calculated as around 127 Mt-CO_2/year as shown in Table 5.

Table 5. Total CDM physical potentials in five sectors in China

Sector	CDM physical potential (1,000 t-CO_2/year)
Power generation	99,350
Iron and steel	4,949
Paper	394–1,172
Cement	13,280
Chemical, oil refinery	8,620
Total	126,593–127,371

As expected, the power-generation sector showed the largest reduction potentials. In the power-generation sector, more than 45% of this would be due to fuel-switching (Table 4). The above figures are 'physical' potentials. The important point here is how much it would cost to reduce 1 tonne of CO_2. In the next section, this point will be examined further.

3. Estimation of CO_2 abatement cost

3.1. Methodology

CDM project costs can be defined as the difference between Equation (1) and Equation (2) below (i.e., the difference between the profit of the baseline case and that of the project case throughout the crediting period, expressed in terms of present value). The present discounted value of the profit of a baseline case is calculated as follows:

$$\sum_{i=1}^{n} \frac{(SB_i - EB_i - MB_i)}{(1+r)^i} \quad (1)$$

where r is the discount rate, which is set at 8% (the value provided by Tsinghua University), n is the crediting period, set at 7, 10, 14, and 21 years, and SB_i, EB_i, MB_i are turnover, fuel cost, and maintenance cost in the year i, respectively.

The present discounted value of the profit of the CDM case is calculated as follows:

$$\sum_{i=1}^{n} \frac{(SC_i - EC_i - MC_i)}{(1+r)^i} - I_0 \quad (2)$$

where SC_i, EC_i, and MC_i are the turnover, fuel cost, and maintenance cost of CDM in the year I, respectively, and I_0 is the initial investment in the CDM activity.

The study assumed that no change would be made to the capacity of facilities, turnover and maintenance costs for the CDM project. Under this assumption, SB_i would be equal to SC_i, and MB_i would be equal to MC_i. Therefore, the present discounted value of the CDM project cost could be calculated as follows:

$$\sum_{i=1}^{n} \frac{(EC_i - EB_i)}{(1+r)^i} + I_0 \quad (3)$$

where $(EC_i - EB_i)$ is the saved fuel cost in the year i.

Next, CO_2 abatement cost, expressed in terms of CDM project cost per unit of CO_2 abatement can be calculated as follows:

$$\frac{\sum_{i=1}^{n} \frac{(EC_i - EB_i)}{(1+r)^i} + I_0}{\sum_{i=1}^{n} Y_i} \quad (4)$$

where Y_i is CO_2 reduction volume in the year i.

As shown by GEF (1996) and the World Bank (2004b), it is theoretically desirable to consider all incremental costs to follow the ICER (incremental cost for emission reductions) approach. In this sense, not only the initial investment costs for CDM cases but also those for existing facilities should be taken into account. However, in the thorough bottom-up approach adopted in this article, only the initial investment cost for a CDM project has been counted (except for 'greenfield' plants, as discussed in Section 6.2). There are three reasons for this. Firstly, accurate data were unavailable. Secondly, most of the older and smaller-capacity power plants were built during the 1960s and 1970s (Table 1), and their initial investments have been fully depreciated. Thirdly, since most of the emission reduction options for energy-intensive industries aim to install additional equipment to existing facilities, it is reasonable to include initial investment only for the CDM projects. Initial investment for baseline case, however, is taken into account for 'greenfield' projects (see Section 6-1).

3.2. Abatement cost calculations in the power-generation sector

Based on the actual data provided by Tsinghua University, including prices of coal and natural gas (the latter being 6.5 times higher than the former) and also using the efficiency improvement ratios in Table 3 for respective model units, the annual fuel cost saving of a type 1 (S&B) model plant, for example, is calculated as ¥214.1 million as well as the CO_2 emission reduction of 255,460 t-CO_2/year. The initial investment cost was calculated, using Japanese data, as ¥2,747.3 million. By the use of these figures and the discount rate of 8%, the abatement cost per t-CO_2 was calculated as ¥913 ($8.3; $1 = ¥110) for a 7-year crediting period.[2]

$$\mathrm{CO_2\ abatement\ cost} = \frac{\left[\sum_{i=1}^{7} \frac{214.1[\mathrm{Myen/yr}]}{(1+0.08)^i} - 2,747.3[\mathrm{Myen}]\right]}{\sum_{i=1}^{7} 255,460[\mathrm{t-CO_2/yr}]} = 913[¥/\mathrm{t-CO_2}]$$

In the same way, the abatement cost for a fuel-switching project for a larger model unit of 300 MW was calculated as ¥6,764 per t-CO_2 (for a 7-year crediting period). The costs corresponding to various model type cases and CDM crediting periods in the power-generation sector are summarized in Table 6.

Table 6. CO_2 abatement costs, power-generation sector (unit: ¥/t-CO_2)

Unit capacity (MW)	Types of CDM	Crediting period (years)			
		7	14	21	10
50	Scrap & build	913 ($8.3)	275	112	513
100	Modification	2,133 ($19.4)	882	516	1,366
200	Modification	3,109 ($28.3)	1,399	873	2,069
300	Fuel-switching	6,764 ($61.5)	4,552	3,490	5,546

3.3. Abatement cost calculations in energy-intensive sectors

As in Section 2, we take the iron and steel sector as an example. As a CDQ facility was to be installed only in large steelworks with more than 1 Mt/year capacity, the same AIJ project (with an annual coke-processing capacity of 450,000 t-coke) in Section 2.2 was not appropriate for the estimation of total reduction volume. Among the few available cases, a case study in Liaoning Province was selected (NEDO, 2002), which was a feasibility study on the installation of a CDQ facility into a 1.2-Mt capacity coke oven. All the figures affecting cost factors were cited from the study. For example, the prices of coke, coal and electricity were set at (Chinese yuan) 300/t, 230/t, and 0.45/kWh, respectively (1 Chinese yuan = Japanese yen (¥)14.78). Also, the initial investment cost was set at ¥3,713 million. The only exception was the reduction ratio of 0.15 t-CO_2/t-coke, which was taken from the AIJ case because of its higher reliability. By applying these figures to Equation (4), the abatement cost per t-CO_2 was calculated as ¥83 (for a 7-year crediting period).

Similarly, the abatement cost per t-CO_2 for a TRT project was calculated as ¥49 (for a 7-year crediting period; NEDO, 2000d). The CO_2 abatement costs of CDQ and TRT are summarized in Table 7.

Table 7. CO_2 abatement costs: iron and steel sector, (unit: ¥/t-CO_2)

Technology	Crediting period (years)			
	7	14	21	10
CDQ	83 ($0.75)	–794	–854	–521
TRT	49 ($0.45)	–1,409	–1,497	–959

The same methodology was applied to other energy-intensive sectors. In the paper-manufacturing sector, however, NEDO's feasibility study on the introduction of energy efficiency technology to a paper plant in the Philippines was referred to as a model case, due to the lack of data in China (NEDO, 1999b).

4. Transaction cost

The transaction cost is one of the factors hindering the promotion of CDM activities. It includes the project finding cost, PDD (project design document) preparation cost (including baseline studies), negotiation cost, validation cost, monitoring cost, verification/certification cost etc. Here, a bottom-up approach was again adopted to estimate the transaction costs for model CDM projects in China. It was assumed that transaction costs would not differ substantially between sectors. The calculation took into account the number of people involved at each stage, their wage per hour, frequency of trips to China including round-trip tickets and hotel charges, and translator fees. The basic figures came from the experiences of Keio/Tsinghua University's 3E (Energy, Economy and Environment) project on CDM, but the discussions of the CDM Executive Board (EB) and other information available from the literature were fully taken into consideration (e.g. Michaelowa and Stronzik, 2002; de Gouvello and Coto, 2003). In addition, fees for validation, verification and certification were incorporated.

For example, the validation fee was set at ¥3 million (average actual figures obtained from the hearings of several operational entities in Japan), and the verification fee was estimated as ¥1 million initially and ¥3 million thereafter (¥0.5 million per year for following 6 years). As a result, the transaction cost per project was estimated as $234,636. Then, assuming that one in five project idea notes (PIN) would be forwarded for approval by the EB, the estimate was increased to $341,909. This figure coincides with the World Bank study estimate of between $310,000 and $335,000 (World Bank, 2002). Table 8 shows the breakdown of the transaction cost.

Table 8. Transaction cost (7-year crediting period)

Items (as per the World Bank classification)	Transaction cost	Transaction cost (assuming 20% success ratio)
Preparation and review of the project (PIN)	26,818	134,091
Baseline study and monitoring plan	46,182	46,182
Validation process	27,273	27,273
Project appraisal	29,273	29,273
Verification & certification, up to 7 years	59,091	59,091
Monitoring fee	36,364	36,364
Other	9,636	9,636
Total	234,636	341,909

5. Economic potential of CDM projects in China

Even if there is found to be a tremendous CDM reduction potential in China, no project will be performed if the reduction cost is much higher than the credit price in the market. Before the Kyoto Protocol entered into force on 16 February 2005, there were several price indications of CERs. The Dutch CERUPT (certified emission reduction unit procurement tender) showed 'maximum' prices, which differed by project type. For example, it set €4.4/t-CO_2 for an energy-efficiency project, and €3.3/t-CO_2 for a fuel-switching project. Another indication comes from the World Bank's recent report (World Bank, 2004a). The report indicated a weighted average price of $3.05/t-$CO_2$ (buyer responsibility case) and $5.52 (seller responsibility case). In view of these indications, this article considers that, at this moment, a CDM project can be economically feasible if its cost (sum of abatement and transaction costs) is less than $5 per t-$CO_2$. This means that the economic potential of a CDM project is equal to the total reduction potential with the abatement cost not exceeding $5/t-$CO_2$.

It should be noted, however, that there are several other factors to be considered for the estimation of CDM potential. One important factor is the governments' (of both host and investing countries) policies toward promotion of CDM. If either government introduces some measures, such as financial incentives, CDM potential will surely be increased even for the same CER prices.

On the other hand, it is easily understood that the costs can differ by the selection of crediting periods. Under CDM procedures, there are four crediting periods: 7, 14, 21, and 10 years. In view of the fact that nothing has been internationally agreed after the year 2013, it will be most reasonable to adopt 7 years as the crediting period. This article, therefore, calculates costs based on a 7-year crediting period unless stated otherwise.

Table 9 shows CO_2 reduction costs, including transaction costs, by sectors/technologies corresponding to different CER prices (with a 7-year crediting period). Column 1 (at the credit price $0/t-$CO_2$) shows a real cost without taking CER price into account. If the figures indicate a negative number, this means that the project will pay. This does not necessarily mean, however, that actual investment will always occur (consider the case where the payback period is more than, say, 5 years). The figures in column 2 are the costs calculated on the assumption that CERs acquired by CDM activities can be sold at $5/t-$CO_2$. The result shows that CDQ and TRT in the iron and steel industry would become feasible at this price. If figures remain positive even at a CER price of $20/t-$CO_2$, such as in most of the power sector technology options, such CDM projects are not economically feasible even at such prices. Table 10 summarizes the information given in Table 9.

Table 9. CO_2 reduction cost (including transaction cost) by sectors/technologies with different prices of CERs (7-year crediting period, US$1 = ¥110)

Sector / CO_2 abatement options	CO_2 emission abatement cost \$/t-CO_2			
	Credit price \$0/t-CO_2	Credit price \$5/t-CO_2	Credit price \$10/t-CO_2	Credit price \$20/t-CO_2
Power sector				
Scrap & build option (50 MW)	8.5	4.8	1.1	–6.4
Improvement of thermal efficiency (100 MW)	22.5	18.8	15.1	7.7
Improvement of thermal efficiency (200 MW)	29.1	25.4	21.6	14.2
Fuel switching (300 MW)	60.1	56.4	52.7	45.3
Steel industry				
Coke dry quenching (CDQ)	1.0	–4.7	–6.4	–13.9
Top pressure recovery turbine (TRT)	0.9	–2.8	–6.5	–13.9
Paper industry	25.9	22.2	18.5	11.1
Cement industry				
Replacement of small vertical kiln with fluidized bed kiln	46.5	42.7	39.0	31.6
Replacement of wet-process kiln with suspension pre-heater	57.4	53.7	49.9	42.5
Waste heat power generation	5.6	1.8	–1.9	–9.3
Utilization of combustible waste as fuel	25.8	22.1	18.3	10.9
Utilization of steel slag for cement material	–2.6	–6.4	–10.1	–17.5
Oil refinery and chemical industry				
Oil refinery gasification of oil residue and power generation	–20.4	–24.1	–27.9	–35.3
Ethylene gas turbine installation and utilization of exhaust gas for cracking furnace	–19.5	–23.2	–26.9	–34.3
Chemical fertilizer coal gasification combined power generation	–4.6	–8.3	–12.0	–19.4
Chlor-alkali (Replacement of diaphragm process with ion-exchange membrane process)	25.2	21.4	17.7	10.3

Table 10. Economic potential of CDM in China (power-generation and energy-intensive sectors)

Price of CER	Economic potential corresponding to CER price	Economic potential in power-generation sector
(\$/t-CO_2)	(1,000 t-CO_2 (cumulative))	
0.0	10,330	0
Up to 5.0	15,279	0
Up to 10.0	17,179	0
Up to 20.0	52,759	35,580
>20.0	126,599–127,369	99,350

It is noteworthy that, although the physical potential of the power-generation sector was the largest, no such projects except for the 'scrap and build' option for 50-MW power units would become economically feasible even at a CER price of $20.

It is also possible to draw a marginal abatement cost (MAC) curve as shown in Figure 2, taking transaction costs into account.

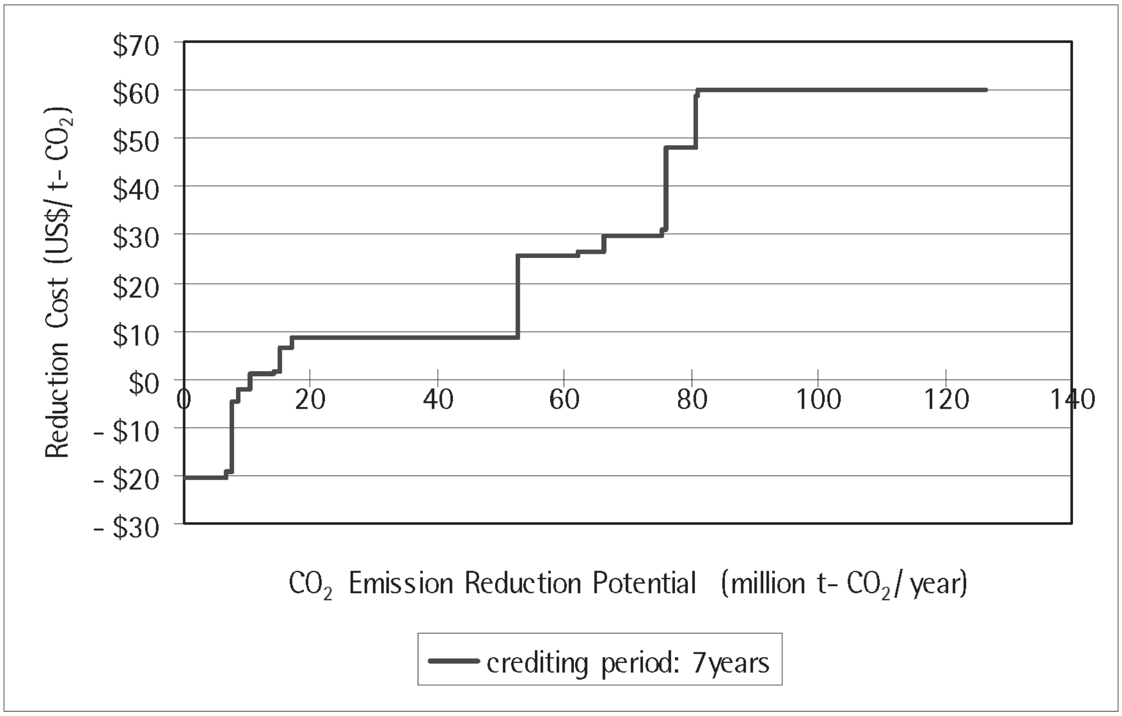

Figure 2. A marginal abatement cost (MAC) CURVE

As stated before, the economic potential of CDM in China was calculated on the basis of the assumed CER price of $5. However, CER prices may vary from time to time. Actually, reflecting the start of the EU emission trading scheme (EU-ETS) from January 2005, the forward price of the EU allowance for the year 2005 has been traded at around €8 ($10)/t-$CO_2$ as of July 2004. In this case, the economic potential of CDM in China will increase by 1.9 Mt. By adopting a bottom-up approach, it is easy to discover how CDM economic potential changes as well as what kind of technologies will be newly introduced as CER prices fluctuate.

Finally, I draw attention to an important factor that might affect CDM economic potential substantially; that is, fuel price. There exist no official statistics on fuel prices in China. In this article, the economic potential of a fuel-switching project in the power-generation sector was calculated based on the actual data (provided by Tsinghua University) showing that the natural gas price was about 6.5 times higher than that of coal (in Shanxi Province). However, it was found later that this difference was only 4.0 times in Inner Mongolia. The reason for this seems to be the difference in distance from a natural gas well (2,500 km in Shanxi Province vs. 400 km in Inner Mongolia). Moreover, fuel prices fluctuate both domestically and internationally. It is reasonable to expect coal prices in China to increase, reflecting their recent rapid economic growth. Actually, the coal price in Inner Mongolia has increased by 6% in 2003 compared with the previous year, according to the data collected through the Tsinghua University research. Although this tendency may be mitigated by the tightening economic policy of China, any fluctuation in fuel prices will surely affect China's CDM economic potential.

6. Other promising areas of CDM potential in China

6.1. CDM potential for 'greenfield' plants in the power-generation sector

Throughout this article, it was tacitly assumed that all CDM projects (including fuel-switching projects in the power-generation sector) were to be carried out on the 'existing' plant. The reason behind this assumption was that, under China's planned economy regime, it would be almost impossible to obtain the host government approval on any CDM project for the 'planned' plants to be newly constructed. The central government might insist that the plan should be pursued as is. However, the latest discussion with a Chinese government official in charge of CDM activity revealed that such a way of thinking might now be changing, reflecting China's transition toward a market economy.

If this is the case, then it would be worthwhile, in view of the recent situation of power shortages in China, to explore CDM potentials on 'greenfield' projects in large power plants with a capacity of 300 MW and upward. The technology applied should be fuel switching from coal to natural gas, with a gas and steam turbine combined cycle. As these 'planned' plants are expected to adopt Chinese state-of-the-art technologies, there is hardly any room for thermal efficiency improvement except for fuel switching. To examine the feasibility of 'greenfield' projects, the Baotou Power Station in Inner Mongolia, with the capacity of two 300-MW power generator units was chosen as a fuel-switching project mainly because of its data availability. It would be reasonable to assume that the cost of initial investment would be the difference between the initial investment amount of the originally planned coal-fired plant (to be borne by the Chinese side) and that of the plant being built under the CDM project.

The result showed a sharp decrease in the initial investment cost of CDM project. The initial investment cost was estimated as $263 million (¥29.0 billion) in Shanxi and $15 million (¥1.7 billion) in Inner Mongolia (down to only one-sixteenth). While the original plan was to build a coal-fired sub-critical power plant equipped with Chinese technologies, the CDM project would be to construct a gas and steam turbine combined cycle plant, which would improve thermal efficiency by 16.9% and reduce CO_2 emissions by 1.8 Mt annually. The abatement cost was calculated as $16.8 (¥1,847)/t-$CO_2$, which was a substantial decrease from $61.5 (¥6,764) in the case of Shanxi Province. About 75% of this difference came from the difference in initial investment costs. Although the abatement cost was still high compared with the current CER price, it indicated that the 'greenfield' fuel-switching project could become economically feasible if the CER price approached $16.8/t-$CO_2$ or when some kind of government incentives was introduced, even below this CER price.

With regard to CDM potential for 'greenfield' plants in the power-generation sector, I would like to mention the outcome of another study that was carried out in parallel to the Keio/Tsinghua 3E project. According to the World Bank (2004b), the annual CDM potential of the power-generation sector was estimated as 10.8 Mt/C (or 39.6 Mt/CO_2) at $6/t-$CO_2$. This figure was derived based on three models: the IPAC (integrated policy analysis model for China) top-down model, the IPAC-AIM

(Asian-Pacific integrated model) bottom-up technology model, and the CERT (carbon emission reduction trading equilibrium model). In Section 5 of this article, the CDM economic potential in the power-generation sector was estimated as zero at the CER price of \$10/t-CO_2. Only when the price of CERs reaches \$20 does the potential become 36 Mt/CO_2. Why such a big difference?

There will be several reasons. One is because the World Bank study is entirely based on a model approach while this article's approach is based on an entirely bottom-up approach (i.e., no model has been used). Though based on models, the World Bank approach introduced an assumption at the final stage that 30% of total potential would be implemented as CDM. If one changes this figure to, say, 20%, the potential will be reduced to 26.4 Mt/CO_2.

There is, however, another important factor. As described above, it was apparent in the process of the 3E study, and through discussions with Chinese officials, that all members concerned (including Chinese experts and professors) believed that no greenfield project would be approved under the centralized planned economy regime. This is why no CDM potential for greenfield projects is included in this study. If it becomes clear that the Chinese government will welcome this kind of project, China's CDM potential will be much larger, in view of the low increment cost for initial investment, although not as big as the World Bank estimates because of a shortage of natural gas supply (including distance from the pipelines). The key issue here is the Chinese Government's policy. Will they aggressively promote this kind of project as CDM or not?

6.2. CDM potential in other fields

So far, this review focuses only on energy efficiency improvement and fuel-switching projects. However, according to the World Bank report, GHG emission reduction (in the year 2003–2004) by HFC_{23} destruction projects rank first (31% of total reduction) followed by landfill gas recovery projects (18%), whereas the share of emission reduction by energy efficiency improvement projects and fuel-switching projects are 6% and 4%, respectively (World Bank, 2004a). It is surprising that such a huge emission reduction has been achieved with only two HFC_{23} destruction projects. The World Bank suggests that the reason is their comparatively cheap reduction cost because of the high global warming potential of HFC_{23}.

However, in Article 4 of the CDM Decree that took effect on 30 June 2004, the Chinese Government has made it clear that their priority projects for CDM would be those of energy efficiency improvement, fuel switching, renewable energy and methane recovery. From this point of view, the Chinese Government is not likely to approve a HFC_{23} destruction project as a CDM project. From this viewpoint, a methane recovery project could be a plausible candidate for a CDM project in China, though no ancillary benefits can be expected.

There was an interesting case study, also presented as the side event at COP-9 (Ninth Conference of the Parties to the United Nations Framework Convention on Climate Change), which demonstrated the inexpensive abatement cost of \$3.6/t-CO_2 for a landfill gas recovery project (Zhao Xiusheng et al., 2003). In order to find more cost-effective CDM projects in China, therefore, further work on landfill gas recovery projects should be pursued.

Finally, it will be worthwhile to explore CDM potential in the field of renewable energy, such as wind farms. Although the initial investment costs are high (World Bank, 2004b), it will have great potential as a CDM project (People's Republic of China, 2004). In fact, a wind-farm project in Inner Mongolia has already been approved as a CDM project by the Chinese government. In addition, this kind of project also contributes to the prevention of air pollution.

7. Conclusions: toward the promotion of CDM activities in China

So far this article has focused on exploring the physical and economic potential of CDM in China and on developing a bottom-up methodology for that purpose.[3] However, the ultimate purpose of the 3E project is to promote CDM projects in China (and other developing countries).

In the face of the entry into force of the Kyoto Protocol, those developed countries that are Members to the Protocol have to comply with their commitments. For this purpose, the Kyoto mechanisms should play a key role. Among the three mechanisms, international emissions trading (IET) will not be utilized fully. Due to the prospect of a huge amount of 'hot-air', especially in Russia, both the EU and Japan, the most plausible buyers of tradable permits are reluctant to purchase them because of the concern that the transaction will lead to an increase in total global emissions. Hence the attention now focuses on both CDM and JI projects. China's CDM potential is estimated to be as large as 50% of total CDM (World Bank, 2004b). Therefore to remove barriers to, and promote incentives for, CDM projects in China will be crucial for the success of the Kyoto regime. At the same time, global cooperation (including that of the major developing countries) is particularly important in order to cope with climate change in a long run. CDM will help to enhance developing countries' capacity to cope with climate change by promoting technology transfer from developed to developing countries. For this purpose there are several recommendations for policy makers.

The first is for the host country government: It is important for the government to set clear rules. Although the Chinese government has revealed their priorities for CDM projects (see Section 6.2), the lists are provisional and the situation is still unclear. For example, the government of China is said to impose 'tax' on the credits earned through projects that are deemed to have less priority, such as HFC_{23} destruction projects. However no concrete figures are given. Also, as discussed in the previous section, it is not clear whether greenfield projects will be approved as CDM projects, provided that all necessary conditions are met. Under the situation of power shortages seen in China today, this will add a huge CDM potential in the field of power generation and will encourage many potential investors. In conclusion, the government of China should set a clear rule, preferably that would help to favor CDM projects that lead to improvements in their energy (or carbon) efficiency in the long term (beyond the Kyoto Protocol period). Another important point is data availability. Lack of data quite often discourages potential investors. Sometimes the government's cooperation in data collection is quite helpful. It will assist potential investors, as well as host country entities, in making decisions with better information and also reduced transaction costs.

For developed country governments, the following actions are recommended. Firstly, as well as cooperating with the developing countries in their capacity-building efforts, it is desirable to establish a scheme to promote CDM activities not only for the purpose of acquiring CERs but also for contributing to the sustainable development of developing countries. In this respect, a new scheme established recently by the Japanese government is worth noting. Starting from April 2005, this scheme will allow paying 'upfront' up to 50% of the total CDM investment amount. More concretely the scheme will pay 'upfront' even before the completion of the project. In exchange, the government will be entitled to receive an appropriate proportion of CERs acquired. Any developing country entities in partnership with Japanese investors can apply for this scheme. Although the details are not yet finalized, it is hoped that the scheme would provide a priority list, in which those projects that can contribute to sustainable development would be given top priority. Energy-efficiency projects that not only reduce CO_2 and other air-pollutant emissions but also contribute to sustainable development of developing countries must be included among them. Secondly, it is recommended that the developed country governments set up a team including insurers (both commercial and government-affiliated export and investment insurance agencies) to evaluate the risks associated with promoting CDM projects and to provide insurance coverage. There are two kinds of risks associated with CDM and JI (joint implementation) activities: i.e., risks unique to these activities, and risks common to projects in general. The former include: political risks on the side of host countries (such as approval of host countries); institutional risks (such as EB approval); and commercial risks (such as CER price fluctuations). The latter include: natural disasters; political risks (e.g., civil war); institutional risks (e.g., revision of regulations); and ordinary commercial risks (nonperformance risk, compliance risk, exchange and interest rate change risks, etc). Providing insurance coverage (against the risks associated with potential CDM projects) can promote CDM activities by hedging risks. The third recommendation is to communicate with host-country governments on the protection of the intellectual property rights. Lack of protection of their intellectual property rights may force potential investors to withdraw. At a glance this seems to contradict the concept of the diffusion of technologies in developing countries. However, without effective regulations concerning the intellectual property rights in developing countries, technology transfer itself is not likely to occur.

Finally, there remains one more important issue; the CDM Executive Board (EB). At the end of January 2005, only two CDM projects were registered to the CDM registry (one is landfill gas and the other is a small hydro project). With more than 60 projects in the pipeline, this suggests that it may take time for these projects to be approved by the EB or, more likely, some projects may never be approved at all. Especially in the field of energy-efficiency improvement, only one methodology has been approved (AM0018), which would not be applicable, for example, to power generation plants. The EB is doing a good job so far. However it is my personal view (and this is not a criticism) that it exclusively pursues a perfect result. Of course it is never desirable for total emissions (both in developed and developing countries) to increase as a result of implementing CDM projects. However, the issue can be described as a chicken-and-egg problem. The EB should set the basic principle called ‘learning by doing’. That is, to let CDM projects be introduced (although cautiously) first, and then try to perfect the system later. There remain only eight years until the end of the first commitment period of the Kyoto Protocol. Turning from perfectionism to a trial-and-error approach would change the situation dramatically in order to promote CDM projects further.

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Notes

1 http://unfccc.int/files/kyoto_mechanisms/aij/activities_implemented_jointly/application/pdf/chijap01-99.pdf
2 It should be noted that, for the purpose of simplicity, a static methodology of ICER, where the total emissions reduction over the period is not discounted, is applied in Equation (4). Although the crediting period is only for 7 years, this means that the cost is overestimated in comparison to the case of a dynamic ICER methodology. I would like to discuss this point in more detail in a future article.
3 This article focuses solely on China. However, I believe that the methodologies set forth here could be applied to other developing countries, especially those where coal-fired power plants have the majority share among the power-generation sector, and the energy efficiencies of heavy industries are not yet sufficiently high (such as India).

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