Part 1

"CDM potential of electric power sector and energy-intensive industries in China"

Summary

This study discusses on the following:

- Methodologies to estimate potential CO_2 emission reduction of CDM options for electric power plants and energy-intensive industries.
- Methodologies to estimate CO_2 reduction cost of CDM options.
- Potential amount and cost of CO_2 emission reduction in electric power sector and energy-intensive industries in China.

The potentials of electric power plants were estimated using the data sets on model units provided by Tsinghua University, and utility companies. The possibilities of CO_2 emission reduction of the energy-intensity industries (steel, paper, cement, and oil refinery and chemical industry), on the other hand, was evaluated with the data from published reports. Main reference was made from the reports of feasibility study projects conducted by NEDO (The New Energy and Industrial Technology Development Organization). It was inevitable to derive the data from various sources due to limited availability. With the heterogeneity of data quality in mind, potential CO2 was estimated using different methodologies for electric power plants and energy-intensive industries.

Contents

1. Estimating CO_2 reduction costs

CDM project cost can be defined as the difference between profit of the baseline[1] case and that of the project case throughout the crediting period, expressed in terms of present value. Present discounted value of the profit of the baseline case is calculated as follows:

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

where r is the discount rate, which is set at 8% in the study, n is the crediting period, set at 7, 10, 14, and 21 years, SB_i EB_i MB_i are sales, fuel cost and maintenance cost in the year i, respectively.

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

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

where SC_i EC_i MC_i are sales, fuel cost and maintenance cost of CDM case in the year I respectively, and I_0 is the installation cost of project (in the year 0).

The study assumes that projects will maintain the current capacity of facilities, and thus sales and maintenance costs are set at identical rates for both cases. With this assumption, SB_i, SC_i, MB_i and MC_i can be eliminated from the calculation. Present discounted value of the CDM project cost can be calculated as follows:

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

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

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

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

where Y_i is CO_2 reduction in the year i.

[1] The study is based on one of the baseline methodologies defined in the Marrakesh Accord (FCCC/CP/2001/L.24/Add.2), which is "existing actual or historical emissions, applicable." Other two methodologies are defined such as: "emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment" and "the average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category."

2. CDM potential and cost of electric power plants in North China and whole China

(1) Estimation of CDM potential

1. Classify electric power plants of North China[2]

In this study, units in North China are categorized into three groups: 50MW units, 100 and 200MW units, and 300MW units. Units smaller than 50MW and larger than 300MW are excluded. The reasons of this exclusion are as follows: (1) small units are difficult to meet cost-effectiveness of CDM; and (2) units larger than 300MW were built after 1990 and highly efficient equipments are already installed.

The description of each group is the following:

Group 1: 50MW units
The units in this group generally use outdated inefficient equipments (almost all units started operation in the 1960's or earlier). In accordance with government policy, those units are to be removed by larger units with Chinese state-of-the-art equipments.
→ "Scrap & build option"

Group 2: 100 and 200MW units
The units in this group are not old enough to be scrapped (the 100MW units started operation in the 1970's or 1980's, and the 200MW units started operation in the 1980's or 1990's). Nonetheless CO_2 emission reduction can be reduced by installing high-efficiency boiler, turbine and auxiliary machinery.
→ "Modification option"

Group 3: 300MW units
The units in this group have relatively highly efficient equipment in place (started operation in the 1990's or after). However those units are coal-fired power plants and thus there is a possibility of CO_2 emissions reduction through fuel switching from coal to natural gas. This option is included in the study for comparing with the other options, although it requires high cost.
→ "Fuel switching option"

2. Select targeted units in North China and China

Total unit capacity in North China is 17,620MW (108 units), of which units of 50MW, 100MW and 200MW account 8,200MW total capacity. Additionally, 5,013MW capacity of 300MW units is selected for the fuel switching option. As a result, 13,213MW capacity is selected as targeted units in North China (it represents 75% of the total unit capacity in North China).

In the same way, 88,165MW capacity of 50MW, 100MW, 200MW and 300MW is selected as targeted units in China. This targeted capacity, 88,165 MW represents 46% of all unit capacity of thermal power plants in China (192,500MW).

[2] Hereinafter, North China refers to Hebei Province, Shanxi Province and the western part of Inner Mongolia Autonomous Region (the study excludes Beijing, Tainjin, the northern part of Hebei Province, and the eastern part of Inner Mongolia).

3. Select model units for respective groups

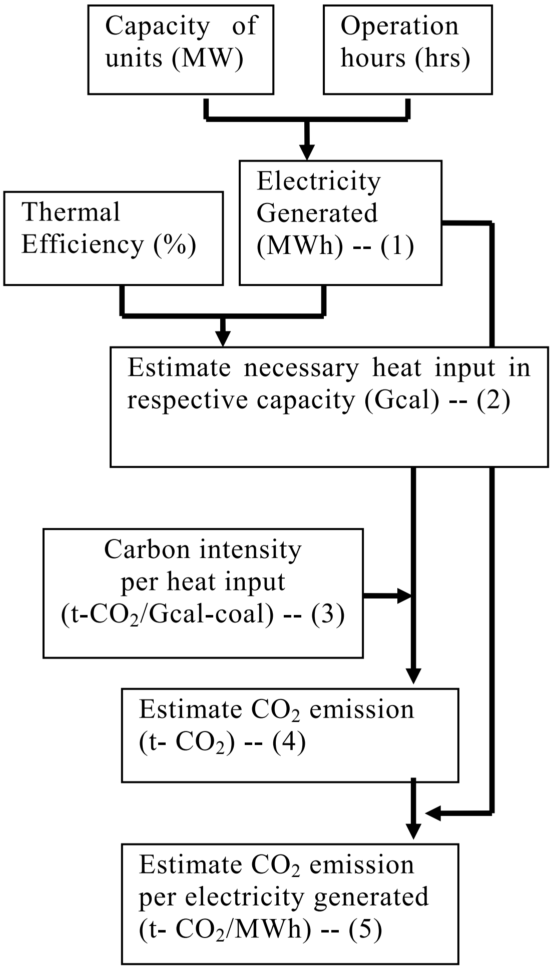
Model units for respective groups are selected to estimate CO_2 emission reduction (Table 1).

Table 1: Groups and Model units[3]

	Unit Capacity	Model Plant
Group 1 Scrap & Build option	50MW	Shanxi, Taiyuan No.2 Electric & Thermal Power Station 50MW * 4
Group 2 Modification option	100MW	Inner Mongolia, Haibowan Electric Power Station 100MW*2
	200MW	Inner Mongolia, Huaneng Fengzhen Electric & Thermal Power Station 200MW*6
Group 3 Fuel switching option	300MW	Shanxi, Taiyi Electric Power Station 300MW*2

3 In order to select model plants, basic information on all electric power units in North China was collected by the cooperation of Tsinghua University. Then, through site surveys and follow-up correspondences, detailed information of the model plants was provided by Tsinghua University and power companies as follows: numbers of generators in power plant and its units capacity, annual electricity generated, annual heat generated, annual heat supplied, location, annual operating hours, annual coal consumption, chemical composition and calorific value of coal, power plant gross efficiency, boiler capacity, steam pressure and temperature at steam turbine inlet and other major specifications, construction cost, maintenance cost, fuel (coal) price, electricity and heat prices for selling, and conditions of waste heat from power plant (temperature and oxygen content of exhaust flue gas).

4. Estimate baseline CO_2 emission



The following steps are taken for calculating baseline CO_2 emission.

(1) Electricity generated is calculated, based on the capacity of units and operation hours.

(2) Heat input is calculated, from electricity generated and thermal efficiency.

(3) Since carbon intensity of coal is not identical among regions, three different carbon intensities are set for each region (Table 2).

(4) CO_2 emission is estimated by multiplying heat input by carbon intensity of coal.

(5) CO_2 emission per electricity generated is calculated from the result of (4). Table3 shows CO_2 emission per electricity generated.

The study applies different carbon intensities for Hebei, Shanxi and Inner Mongolia, since the carbon intensity of coals varies in each region. Table 2 shows the carbon intensity for each region[4]. In addition, CO_2 emissions per MWh for respective capacity are calculated, based on the different carbon intensities of coals in the regions (Table 3).

Table 2: Carbon intensities of coals in three regions

Region	Hebei	Shanxi	Inner Mongolia
Carbon intensity (t- CO_2/Gcal)	0.378	0.415	0.402

[4] The carbon intensity for estimating CO_2 emission reduction in China represents the average value of the three different intensities of Hebei, Shanxi and Inner Mongolia.

Table 3: CO_2 emission per MWh for respective capacity and areas (t-CO_2/MWh)

	Hebei	Shanxi	Inner Mongolia
50MW	1.012	1.111	1.077
100MW	0.957	1.065	1.032
200MW	0.926	1.065	1.032
300MW	-	0.982	-

Notes: The number of 300MW in Shanxi is actual figure in the model plant.

5. Estimate CO_2 emission of CDM case

Using the same method, CO_2 emission of CDM case is estimated. Table 4 shows the rates of improvements of thermal efficiency as a result of scrap and build, modification or fuel switching.

CO_2 emission reduction can be estimated by comparing the difference in CO_2 emission between the baseline and CDM cases.

Table 4: Summary of improved thermal efficiency of model units

	50MW(scrap&build)		100MW (Modification)	200MW (Modification)	300MW (Fuel switching)
	to 100MW	to 200MW			
Improved efficiency (Boiler and Turbine)	25.9%	30.2%	2.9%	3.1%	12.0%

Notes: (1) For 100MW and 200MW model units, in addition to the above improvements of thermal efficiency of boiler and turbine, CO_2 emission reduction is expected as a result of reduced energy use due to replacement of auxiliary equipments such as pulverizers.

(2) The study assumes that except gas turbines, Chinese equipments (steam turbine, boiler and etc.) are installed into the units.

(6)Extrapolate CO_2 emission reduction of targeted units in North China

Potential amount of CO_2 emission reduction in North China and whole China is estimated as a result of multiplying the calculated carbon intensities by total capacity of targeted units. At this estimation, operation hours are assumed to be the same as present. Table 5 summarizes the result of the calculations:

Table 5: Summary of CO_2 emission reduction potential in North China and China

	50MW	100MW	200MW	300MW	Total
North China					
Total capacity of the targeted units (MW)	1,000	2,000	5,200	5,013	13,213
CO_2 emission reduction(1000t/y)	2,142	524	1,270	12,411	16,347
China					
Total capacity of the targeted units(MW)	5,460	27,405	36,900	18,400[5]	88,165
CO_2 emission reduction(1000t/y)	11,695	7,180	9,004	45,550	73,429

5 In selecting targeted units for the fuel switching option, the total capacity represents all power plants which are closer than 10 kilometer from existing or planed gas pipelines. Availability of gas supply is not considered in the study. Please note that although potential amount of CO_2 reduction of 300MW fuel switching option is tremendous, it would be the most expensive project among the options, as shows in the Table 8 and 9.

(2) Estimation of CO_2 emission reduction cost

CO_2 emission reduction cost is estimated using the methodology explained in Section 1. Estimated figures in Table 6 represent the modification option in 100MW units (installation of highly efficient burner and seal into boiler).

With installation of high-efficiency boiler, CO_2 emission reduction can be expected as a result of saving coal consumption. The following table shows costs and CO_2 emission reduction of the energy efficiency CDM project placed in 100MW unit.

Table 6. Costs and CO_2 emission reduction of CDM project in Haibowan Electric Power Station in Inner Mongolia

Installation cost of the equipment	$ 3.03 million
Coal consumption	616,807 t-coal/yr
CO_2 emission	1,235,400 t- CO_2/yr
CO_2 emission reduction	14,373 t- CO_2/yr
Saved fuel cost	$ 111,000 /yr
Electricity sales	$ 25.33 million/yr
Maintenance cost	$ 6.45 million/yr

Notes: The data is based on the two units with capacity of 100MW each in Haibowan Electric Power Station.

Fuel prices are set as the following:

Table 7. Fuel prices

Fuel	Price	Price per calorific value
Coal	115 - 126 yuan/t (14 - 16 US$)	2.1 – 2.3 US$/$10^6$kcal
Natural gas	1.2 yuan/m3 (0.15 US$)	17.6 US$/$10^6$kcal

Note:
1) Coal price is set differently in each region. Data was provided by the local utility companies.
2) For calculation of calorific value, the following assumption is applied: 7,000Mcal/t-coal, 8,500kcal/m^3-natural gas.
3) 1US$=8yuan

If it is assumed that n = 14 (years), r = 8%, the CO_2 reduction cost for this option can be calculated as:

$$CO_2 \text{ reduction cost } [\$/t\text{- } CO_2] = \frac{\left[\sum_{i=1}^{14} \frac{111{,}000\,[\$/\mathrm{yr}]}{(1+0.08)^i} - 3.03[M\$]\right]}{\sum_{i=1}^{14} 14{,}373[t - CO_2 / yr]}$$

7.6 [$/t- CO_2]

Table 9 shows CO_2 emission reduction costs for all the other options.

3. CDM potentials and CO_2 emission reduction costs of energy-intensive industries in whole China

To explore other cost effective CDM potentials in other than the electric power industry, the scope of the study is expanded to the energy-intensive industries such as steel, cement, oil refinery, chemical and paper industries. In order to have experts' inputs in selecting feasible technologies for CDM, a working group is formed, which consists of 13 members, including academia, Government and representatives from respective industry above. The working group proposes targeted technologies listed in Table8. Estimated figures represent the maximum capacity of all plants that are not equipped with targeted technologies but have opportunities for installation under the current condition. The data is excerpted from literatures, feasibility study reports of NEDO, and interviews to experts.

1. Select targeted plants in China

Targeted plants are selected for the study, based on the criteria for each CO_2 abatement options. The criteria are shown in the Table 8.

Table 8. Criteria for selecting targeted plants in respective options for CDM

Sector / CO_2 abatement options	Criteria for selecting targeted plants
Steel Industry	
Coke Dry Quenching (CDQ)	- Plants that exceed the annual capacity of pig iron of 1 Mt are selected. - Plants that already installed CDQ in the year 2002 are excluded.
Top Pressure Recovery Turbine (TRT)	- Blast furnaces that exceed 1000m^3 are targeted for the estimation. - Plants that already installed TRT by the time of March 2001 are excluded.
Paper Industry[6]	- Plants that exceed its annual paper production of 10,000t are targeted for the estimation.
Cement Industry	
Replace of small vertical kiln with fluidized bed kiln	- Based on the national policy of scrapping vertical kiln, the study assumes that 10% of cement production from vertical kiln is replaced with cement produced by fluidized bed kiln.
Replace of wet-process kiln with Suspension Pre-heater	- Since it is expected that, even in business-as-usual case, wet-process kilns are converted to suspension Pre-heater to some extent, the study assumes that 10% of cement production from wet-process is additionally replaced with cement from SP kiln through CDM.
Waste heat power generation	- All kilns that exceed its capacity of 2,000t/day are targeted for the estimation.
Utilize of combustible waste as fuel	- All kilns that exceed its capacity of 2,000t/day are targeted for the estimation.

6 For paper industry, the study assumes that the following technologies are installed: replacement of main motors/main auxiliary motors with variable speed motors, use of high efficiency motors as main motors/main auxiliary motors, remodeling into energy saving screens, installation of stationary syphons and spoiler bars for dryer rolls and installation of closed type dryer hood and waste heat recovery equipment for dryer.

	Utilize of steel slag for cement material	- Considering that the feasibility of slag supply is still unknown in China, the study assumes that 10% of cement production in new suspension Pre-heater utilizes steel slag.
Oil Refinery and Chemical Industry		
	Oil Refinery （Gasification of oil residue and power generation）	- Based on the information of reference materials, targeted refineries are specifically selected.
	Ethylene（gas turbine installation and utilize of exhaust gas for cracking furnace）	- Based on the information of reference materials, targeted refineries are specifically selected.
	Chemical fertilizer （Coal gasification combined power generation）	- Considering that a national policy encourages coal gasification and material switching from coal to natural gas, the study assumes that combined power generations are installed and produce 10% of ammonia production in medium-size plants that use coal.
	Clor-alkali （Replace of diaphragm process with ion-exchange membrane process）	- Considering that a national policy promotes conversion from diaphragm process to ion-exchange membrane process, the study assumes that ion-exchange membrane produces additional 10% of soda production, replacing diaphragm process through CDM.

2. Select model plants for respective options

Model plants[7] for CDM are selected for the purpose of evaluating CO_2 emission reduction, which can be expected as a result of introducing CO_2 abatement options. The reports of feasibility study projects conducted by NEDO are referred in order to select model plants. The targeted facilities for study are located in China. Paper industry is the only exception; since no appropriate study in China is found, a study on Philippine paper plants that was conducted by NEDO is referred instead.

3. Estimate CO_2 emission reduction due to CO_2 abatement options

In CDM case, as a result of reduced energy use in model plants, CO_2 emission reduction is expected. Baseline emission of a model plant is set at current emission level. CO_2 emission reduction is estimated by comparing the difference in CO_2 emission between the baseline and CDM cases.

[7] Model plants are selected from the plants assessed by NEDO's feasibility study projects.

4. Extrapolate CO_2 emission reduction of targeted plants in China

Potential amount of CO_2 emission reduction in China is estimated as a result of multiplying the emission reduction in a model plant by total productions of targeted plants in China.

* With regard to paper industry, a different process of estimating CO_2 emission reduction is applied due to limited availability of data. First, total energy saving of targeted plants in China is calculated as a result of multiplying the rate of energy saving in a model plant by total energy use of targeted plants in China. Then potential amount of CO_2 emission reduction is estimated as a result of multiplying carbon intensities of energy (here energy means coal and electricity that are used as primary energy sources in Chinese paper industry) by total energy saving.

4. Summary table of the estimations

The following Table 9 and Table 10 show the estimations of potential amount and cost[8] of CO_2 emission reduction for respective options.

Figure 1 shows marginal cost curves of CDM projects in China, based on the CO_2 emission reduction costs of the CDM options (Table 9).

Figure 2 shows how CO_2 reduction potentials change corresponding to different credit prices. With zero credit price, only CDM options in oil refinery and chemical industry, and one CDM option of cement industry can be realized. However, with credit price of 4.5US$/t-$CO_2$, options of steel industry will be feasible.

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[8] In estimating the costs, fuel prices are set at the following rates, based on the NEDO's reports.

	Coal	Electricity
Steel, Cement, and Oil Refinery and Chemical Industries	177 yuan/t	0.45 yuan/t
Paper Industry	115 yuan/t	0.47 yuan/t

Table 9. Potential Amount and Cost of CO_2 Emission Reduction of CDM Options in China (1/3)

($1 = 110 Japanese yen)

Sector / CO_2 Abatement Options	Reduction Potential (10,000t-CO_2/yr)	Cost[9]			Preparation period (designing～installing facility)	Summary of a model plant	Notes
		CO_2 Reduction Cost (US$/t-$CO_2$)		Payback, years			
		Crediting period: 7yrs	Crediting period: 14yrs				
Power Sector（excluding fuel switching for 300MW units）[total potential incl. 300MW]	2,788 [7,343]	-	-	-	-	-	-
Scrap & build option (Replace 50MW unit with 200MW unit)	1,170	8.3US$	2.5US$	-	Maxium 3 years	・ Replace four 50MW coal-fired power plants with one 200MW unit of coal-fired power plant ・ Initial cost：$25 million ・ Annual CO_2 reduction：255,460(t-CO_2/yr)	・ The baseline is set at the current emission level assuming that CO_2 is emitted from conventional coal-fired power plants. However, if inefficient plants will be replaced by China, the potential of CDM projects becomes small considerably.
Improvement of thermal efficiency option for 100MW unit	718	19.4US$	8.0US$	-	3 months	Installation of highly efficient burner and seal into the boilers in two 100MW units of coal-fired power plant ・ Initial cost：$2.2 million ・ Annual CO_2 reduction：14,373(t-CO_2/yr)	・ The potential is calculated by multiplying the reduction of a model unit (data derived by Tsinghua University) by total capacity in China. The estimation does not consider whether energy efficiency equipment is installed in each unit. ・ The reduction potential is realized by installations of high-efficiency boiler, turbine and auxiliary machinery.
Improvement of thermal efficiency option for 200MW unit	900	28.3US$	12.7US$	-	3 months	・ Installation of highly efficient burner and seal into the boilers in six 200MW units of coal-fired power plant ・ Initial cost：$13 million ・ Annual CO_2 reduction：57,031(t-CO_2/yr)	
Fuel switching from coal to natural gas for 300MW unit	4,555	61.4US$	41.4US$	-	10 months	・ Fuel switching from coal to natural gas for two 300MW units of coal-fired power plant ・ Initial cost：$264 million ・ Annual CO_2 reduction：1,485,330(t-CO_2/yr)	・ Considering that most of the 300MW units were built after 1990s, further study is needed to deploy fuel switching in 300MW units.
Steel Industry	574	-	-	-	-	-	-
Coke Dry Quenching (CDQ)	476	1.6US$	(-15.3US$)[10]	7.3	Approx. 2 years	・ Install CDQ, which has annual capacity of cokes of 1.2 Mt (137t/hour). ・ Initial cost：$34 million ・ Annual CO_2 reduction：85,300(t-CO_2/yr)	・ Plants that exceed the annual capacity of pig iron of 1 Mt are targeted for the estimation. Those plants account for 30% of the total capacity in China. Plants that already installed CDQ in the year 2002 are excluded from the estimation.

9 Setting a discount rate at 8% identically, installation costs and saved fuel costs are calculated in terms of net present value (NPV). Cost is converted in dollar term at the rate of 120yen/US$.

10 Negative values indicate that CDM projects generate profits without any revenue of CO_2 credits. Since it will be possible that host countries insist their claim to the profits from projects, careful evaluation will be required. For this reason, the number is in brackets.

Table 9. Potential Amount and Cost of CO_2 Emission Reduction of CDM Options in China (2/3)

Sector / CO_2 Abatement Options	Reduction Potential (10,000t-CO_2/yr)	Cost[11] CO_2 Reduction Cost (US$/t-$CO_2$) Crediting period: 7yrs	Crediting period: 14yrs	Payback, years	Preparation period (designing～installing facility)	Summary of a model plant	Notes
Top Pressure Recovery Turbine (TRT)	98	0.5	(-15.6)[12]	7.1	Approx. 2 year	• Install TRT into a blast furnace with the annual capacity of pig iron of 1.8 Mt (5,700t/day). • Initial cost：$27 million • Annual CO_2 reduction：71,500(t-CO_2/y)	• Blast furnaces that exceed 1000m^3 are targeted for the estimation. Those blast furnaces are 50 units out of 3200 total units in China. 90% of the blast furnaces in China is smaller than 100m^3. Plants that already installed TRT by the time of March 2001 are excluded from the estimation.
Paper Industry[13]	(40 - 117)	(21.1)	(0.9)	(14.9)	(1)3-4month (2)2-3month (3)4-5month (4)3month (5)6-9month	• Install the following equipments into a plant that produces paper products of 0.24 Mt annually: (1) Replacement of main motors/main auxiliary motors with variable speed motors, (2) Use if high efficiency motors as main motors/main auxiliary motors, (3) Remodeling into energy saving screen, (4) Installation of stationary syphons and spoiler bars for dryer rolls, (5) Installation of closed type dryer hood and waste heat recovery equipment for dryer. • Initial cost：$3.3 million • Annual CO_2 reduction：9,252(t-CO_2/y)	• Due to limitations of data, the data of a feasibility study held in Philippine is referred. Some modifications are done for an appropriate estimation such as the adjustment of price of fuel. Yet because the model plant in Philippine used for the estimation is very large and expects relatively large-scale energy saving effect, the estimation for Chinese plants is likely to be exaggerated than its real amount.
Cement Industry	1,328	-	-	-	-	-	-
Replacement of small vertical kiln with fluidized bed kiln	480	45.0	21.4	-	3 years	• Introduce kiln with klinker production capacity of 700t/d • Initial cost：$11 million • Annual CO_2 reduction:32,600t-CO_2	• Pursuant to the national policy of scrapping vertical kiln, it assumes that 10% of cement production from vertical kiln can be replaced with cement from fluidized bed kiln.
Replacement of wet-process kiln with Suspension Pre-heater	36	55.9	26.2	-	3.5 years	• Introduce kiln with klinker production capacity of 700t/d • Initial cost：$13 million • Annual CO_2 reduction:31,000t-CO_2	• Since it is expected that even in business-as-usual case wet-process kilns will be converted to suspension Pre-heater to some extent, CO_2 reduction potential is calculated with assumption that 10% of cement production from wet-process can be additionally replaced with cement from SP kiln through CDM.
Waste heat power generation	190	8.9	(-5.2)	9.8 years	3 years	• Installation to kiln with cement production capacity of 4,000t/d • Initial cost：$12 million • Annual CO_2 reduction:47,000t-CO_2	• Kilns that exceed 2,000t/d (total capacity: 159,700t/d) are targeted for the estimation.

11 Setting a discount rate at 8% identically, installation costs and saved fuel costs are calculated in terms of net present value (NPV).
12 Negative values indicate that CDM projects generate profits without any revenue of CO_2 credits. Since it will be possible that host countries insist their claim to the profits from projects, careful evaluation will be required. For this reason, the number is in brackets.
13 Note that since the potential of paper industry is estimated with a different methodology due to the limited availability of data.

Table 9. Potential Amount and Cost of CO_2 Emission Reduction of CDM Options in China (3/3)

Sector / CO_2 Abatement Options	Reduction Potential (10,000t-CO_2/yr)	Cost[14] CO_2 Reduction Cost (US$/t-$CO_2$)		Payback, years	Preparation period (designing～installing facility)	Summary of a model plant	Notes
		Crediting period: 7yrs	Crediting period: 14yrs				
Utilize of combustible waste as fuel	426	25.0	10.2	-	2 years	・Introduce to new suspension pre-heater with cement production capacity of 1Mt/yr ・Initial cost：$14 million ・Annual CO_2 reduction:60,000t-CO_2	・Kilns that exceed 2,000t/d (total capacity: 159,700t/d) are targeted for the estimation. ・A project baseline depends on whether the combustible waste has been incinerated in the project area.
Utilize of steel slag for cement material	196	(-2.9)[15]	(-3.1)	3.1 years	3 years	・Installation of vertical mill(1,200kW, 40t/h) ・Initial cost：$4.4 million ・$CO_2$ reduction:0.332t-CO_2/t-cement	・Considering that the feasibility of slag supply is still unknown in China, it assumes that 10% of cement production from new suspension pre-heater utilizes steel slag. ・CO_2 reduction cost takes no account of the cost of slag supply and carriage.
Oil Refinery and Chemical Industry	862	-	-	-	-	-	-
Oil Refinary（Gasification of oil residue and power generation）	670	(-20.4)	(-23.3)	3.3 years	3.5 years	・Installation of generation plant of 228MW into refinery with capacity of 12 million ton/year of crude oil input ・Initial cost：$273 million ・Annual CO_2 reduction:1,600,000t-CO_2	・Oil residue with low sulfur content is utilized to some extent in usual manner. ・Targeted refineries are chosen from the NEDO reports.
Ethylene（gas turbine installation and utilize of exhaust gas for cracking furnace）	94	(-19.8)	(-33.5)	4.9 years	2 years	・Installation of gas turbine of 35MW to ethylene plant with annual production of 650,000 t ・Initial cost：$50 million ・Annual CO_2 reduction:117,000t-CO_2	・Targeted ethylene plants are chosen from the NEDO reports.
Chemical fertilizer （Coal gasification combined power generation）	73	(-4.7)	(-5.8)	3.8 years	2 years	・Installation to ammonia plant with production capacity of 1,000 ton/day ・Initial cost：$27 million ・Annual CO_2 reduction:540,000t-CO_2	・Combined power generation plant also saves energy consumption in producing ammonia from natural gas, but it is not effective in respect of CO_2 reduction. ・Considering the policy that promotes coal gasification and material switching from coal to natural gas, it assumes that 10% of medium size plants derived from coal installs combined power generation.
Clor-alkali（Replace of diaphragm process with ion-exchange membrane process）	25	24.7	7.5	-	2 years	・Introduce to sodium hydroxide plant with production of 100,000t/yr ・Initial cost：$19 million ・Annual CO_2 reduction:110,000t-CO_2	・Considering that the national policy promotes conversion from diaphragm process to ion-exchange membrane process, it assumes that ion-exchange membrane produces additional 10% of soda, replacing diaphragm process through CDM.
[Reference] Waste power generation	2,195	16.6	5.9	-	-	-	-

[14] Setting a discount rate at 8% identically, installation costs and saved fuel costs are calculated in terms of net present value (NPV).

[15] Negative values indicate that CDM projects generate profits without any revenue of CO_2 credits. Since it will be possible that host countries insist their claim to the profits from projects, careful evaluation will be required. For this reason, the number is in brackets.

Table 10. CO_2 emission reduction cost with different prices of CO_2 credits

(Crediting Period:7years, $1 = 110 Japanese yen)

Sector / CO_2 Abatement Options	CO_2 Emission Reduction Cost （$/t-$CO_2$）			
	Credit Price $0 / t-$CO_2$	Credit Price $4.5 / t-$CO_2$	Credit Price $9.0 / t-$CO_2$	Credit Price $18.0 / t-$CO_2$
Power Sector				
Scrap&build option (50MW)	8.3	4.9	1.5	-5.2
Improvement of thermal efficiency (100MW)	19.4	16.0	12.6	5.9
Improvement of thermal efficiency (200MW)	28.3	24.9	21.5	14.7
Fuel switching (300MW)	61.4	58.1	54.7	48.0
Steel Industry				
Coke Dry Quenching (CDQ)	1.6	-1.8	-5.2	-11.9
Top Pressure Recovery Turbine (TRT)	0.5	-2.8	-6.2	-13.0
Paper Industry	21.1	16.9	14.3	7.5
Cement Industry				
Replace of small vertical kiln with fluidized bed kiln	45.0	41.7	38.3	31.5
Replace of wet-process kiln with Suspension Pre-heater	55.9	52.5	49.1	42.4
Waste heat power generation	8.9	5.5	2.2	-4.6
Utilize of combustible waste as fuel	25.0	21.6	18.3	11.5
Utilize of steel slag for cement material	-2.9	-6.2	-9.6	-16.4
Oil Refinery and Chemical Industry				
Oil Refinary（Gasification of oil residue and power generation）	-20.4	-23.8	-27.2	-34.0
Ethylene（gas turbine installation and utilize of exhaust gas for cracking furnace）	-19.8	-23.2	-26.6	-33.4
Chemical fertilizer （Coal gasification combined power generation）	-4.7	-8.0	-11.4	-18.2
Clor-alkali （Replace of diaphragm process with ion-exchange membrane process）	24.7	21.3	18.0	11.2

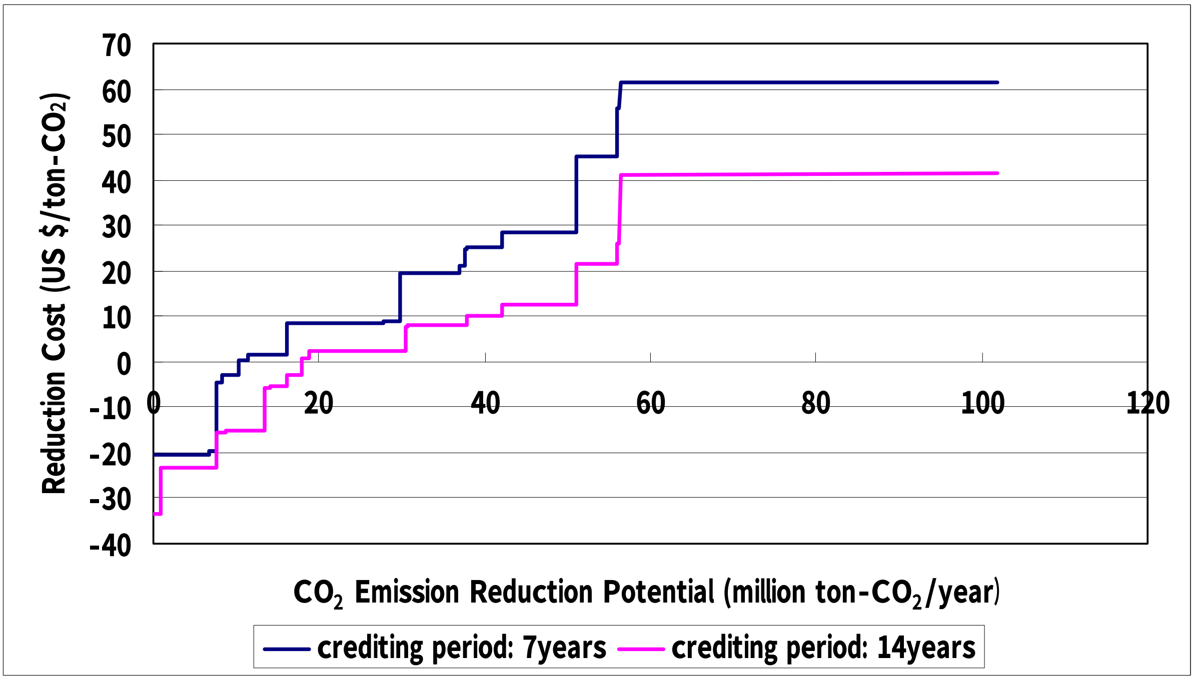

Fig. 1. Marginal Cost Curve of CDM in China

Note: Negative cost indicates that CDM projects generate profits as a result of savings on fuel costs through improvements of energy efficiency.

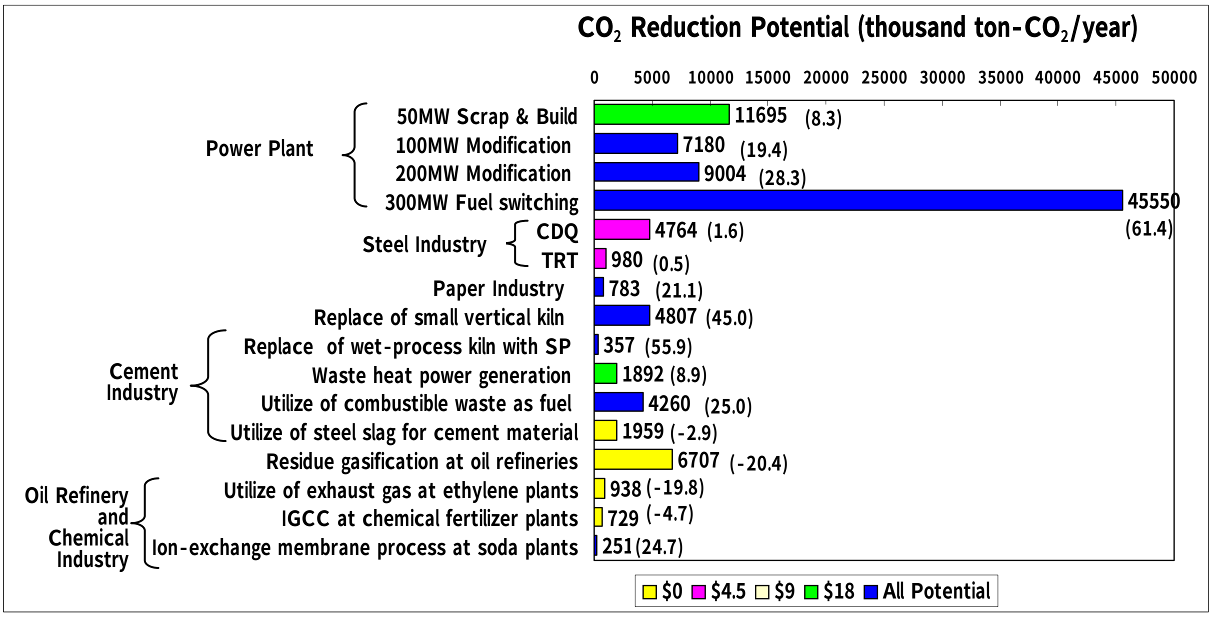

Fig. 2. CO_2 reduction potentials by credit prices

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Annex: Member of 3E CDM Committee, Japan

Chairperson:

Dr. Mitsutsune Yamaguchi	Professor, Faculty of Economics, Keio University

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Mr. Kazuo Imada	Japan Chemical Industry Association
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Mr. Minoru Fujii	Hitachi Engineering Co., Ltd.
Mr. Kaoru Maeda	Japan Consulting Institute
Dr. ZhiDong Li	Associate Professor, Dept. Of Management and Information Systems Science, Nagaoka University of Technology

Part 2

Methodology for Estimating CO2 Emission Reduction And Its Application to North China

Summary

Since electric power stations are generally scattered over a wide area in China and their unit capacities and efficiencies vary greatly, it may be not practical to predict the total CO2 emission reduction by calculating such for one by one unit and also collection of a lot of detailed technical data is a time-consuming job a lot of money is necessary. Therefore, prediction of the CO2 emission reduction potential caused by energy consumption in whole China costs a lot, and so we focused on the power stations in North China and have tried to estimate realistic data of CO2 emission reduction potential based on the existing actual data of power stations in North China. The grand total of CO2 emission reduction in whole China has been also predicted by extending the results calculated for the power stations in North China. The methodology introduced in the research project for predicting CO2 emission reduction in North China or whole China will be possible to apply to developing countries.

About 90% of power stations in China utilize coal as fuel and, since most of them are difficult to change the fuel to natural gas from the geographical condition, we considered that for the purpose of the CO2 emission reduction from coal-fired power stations improvement of gross efficiency of power unit by raising the efficiencies of boilers and auxiliary equipments is realistic and cost effective.

The number of power stations in North China reaches over 100 and it seemed to be almost impossible to obtain the detailed data to estimate CO2 reduction potential satisfactorily. Then we gathered the data of power stations, such as power unit capacity, starting year of operation and so on, in the south region of Hebei, Shanxi and west region of Inner Mongolia with the aid of Tsinghua University. Based on the data, considering the policy of Chinese government to replace deteriorated small-scale and inefficient power units with advanced large-scale and efficient units, the power stations established in each region were classified into 3 groups, that is, scrap and build case, limited modification case and large-scale modification case. After selecting a representative power station from each group in each region, we could gather detailed data almost necessary to estimate CO2 reduction potential by the understanding and cooperation of persons concerned of power stations and Tsinghua University. Using the data, we estimated the possibility of improvement of gross efficiency in each power equipment based on the improvement of heat recovery rate, efficiencies of boiler and auxiliary equipments. From the results of estimation at the representative power stations, the CO2 emission reduction in other same kind power stations was also estimated and then the CDM potential for reduction of CO2 emission from power stations in North China has been verified.

According to the estimation, for the group of 50 MW power units starting their operation in 1970's or earlier, CO2 reduction potential of 3.63 Mt will be expected by gathering small scale boilers and turbines to large scale ones, and moreover 0.13 Mt CO2 reduction by improving the efficiencies of auxiliary equipments.

For the power units of 100 MW class, 0.36 Mt of CO2 will be reduced by remodeling to improve the efficiency, 0.17 Mt of CO2 by improvement of efficiency of auxiliary equipments, and for the power units of 200 MW class, 0.93 Mt of CO2 will be reduced by remodeling, and 0.34 Mt of

CO2 by improving the main auxiliary equipments. By summing up CO2 reduction at power stations in North China 3.63 Mt of CO2 reduction will be expected.

Moreover, in the case of power stations planning in North China, CO2 reduction potential will reach 1.57 Mt if the power stations are constructed by applying the latest and commercialized technologies of Japan (designed for super critical pressure) , when the case they are constructed by applying the Chinese latest technologies is adopted as the base line.

Since the CO2 reduction cost is very important matter when the CO2 reduction mentioned above is conducted as one of the objective of CDM, we expect the active attitude of Chinese side against CO2 reduction. According to our field investigation of power stations in North China, most of engineers working in power stations seemed to have more active attitude toward SOx than CO2 reduction, and they concentrates their eagerness on reduction of SOx and cut of power generation cost by saving energy. However, energy saving to reduce CO2 emission produces the same results as the cut of the power generation cost, then, we think, it is essential matter to conduct capacity building on CDM and to make the person concerned in China understand the meaning of CO2 reduction by CDM project.

Contents

This is a brief description of joint research work between Keio University and Tsinghua University over the past four and half years.
The purposes of the research work are, firstly a development of a methodology for precisely estimating CO2 reduction potential in China and in developing countries, and secondly an

application of the methodology so developed to North China region (including Hebei province, Shanxi province and the western part of Inner Mongolia) for the purpose of calculating CO2 emission reduction potential in the coal-fired power stations in China, whose capacities and performances vary considerably.
The reason for choosing coal-fired power plants is that 91 % of the power generators in China are coal-fired and will remain the primary fuel for electric-power generation in China as well as many developing countries for the foreseeable future

１. Prediction Methodology of Estimating CO2 Emission Reduction

(1) Object of research work (Refer to Fig. 1(1)A,B)

There are electric generating installations with a total capacity of 17,620 MW in North China, Hebei, Shanxi provinces and the western part of Inner Mongolia Auto. Reg.
The total capacity consists of 108 installations and their unit capacities range from 50MW to 300MW, as shown below and in Fig. 1(1) A and B.

Region	North China (Hebei, Shanxi and the western Inner Mongolia)
Total Electric Power Installation selected	17,620 MW
Power Generator Unit Capacity	26×50MW
	28×100MW
	30×200MW
	24×(300MW～350MW)

Object of the Research Work

Unit Capacities	50MW to 200MW (excluding units built after the 1990’s)
Numbers of Unit	66 units in 21 Power Stations
Total Capacity	8,200MWW
Total CO2 Emission	49,000,000 ton / Year

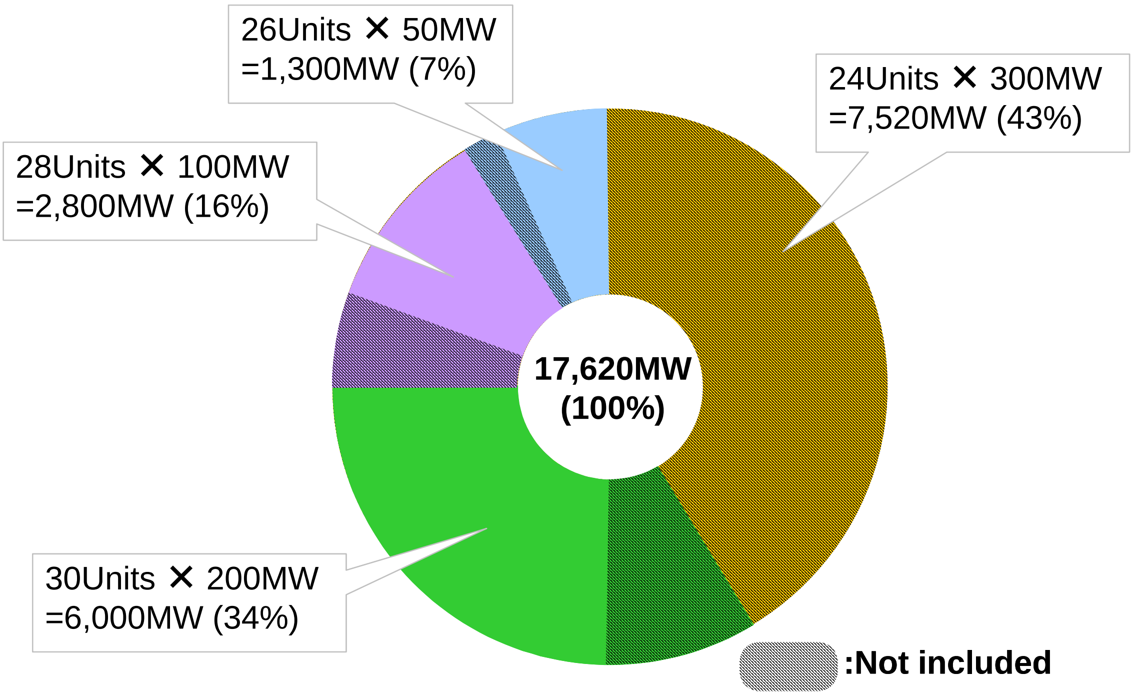

Fig. 1(1)A Object of Research Work

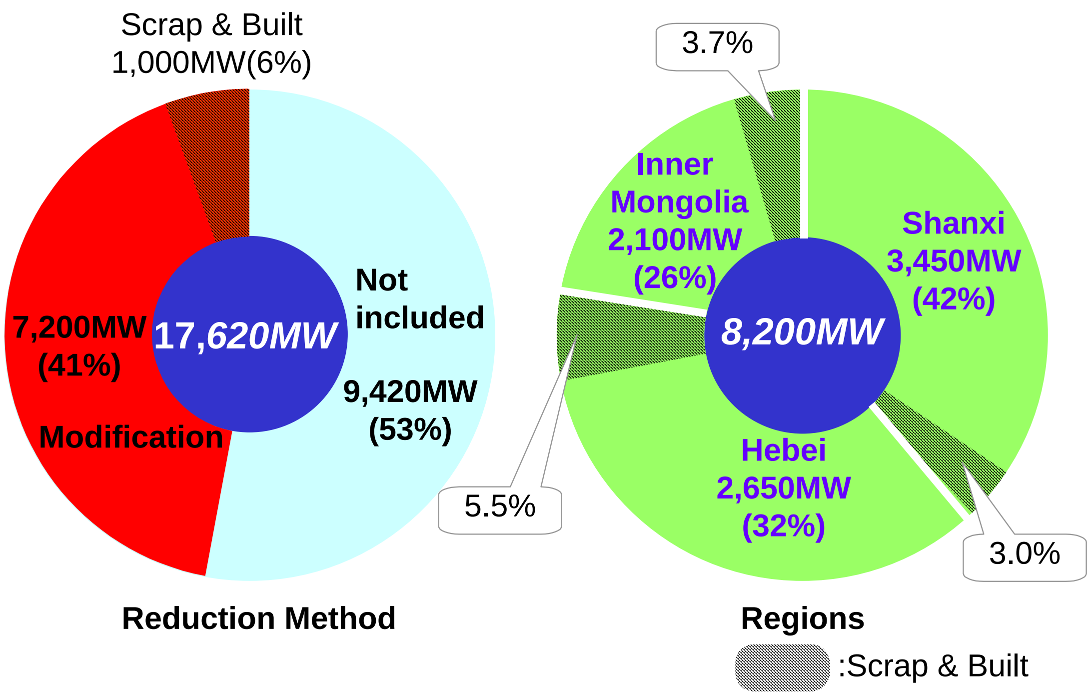

Fig. 1(1)B Regions and Installation

(2) General situation of Chinese electric power generators

Regarding the results of the survey, the overall characteristics of the Chinese electric power industry are shown below.

- Standardized unit capacity 50MW, 100MW, 200MW, 300MW and 600MW
- Fossil fuel (coal, oil, gas) 91% of the fuel for electric power generation is coal.
- Unit capacity Same capacity units were built in about the same era
  Almost all 50MW units started operation in the 1970's or earlier.
  100MW in the 1970s and the 1980s
  200MW in the 1980s and the 1990s
  300MW in the 1990s and after
  Almost all 600MW units started operation since the present decade
- Maintenance of the Installation
  Power station installations are maintained in various ways, with likewise varying deterioration of performance including efficiency.
- Government direction The government has an important influence on key industries such as electric power companies.

Fig, 1 (2) Situation of Electric Power Generators in China: This shows the change of the unit capacities over time

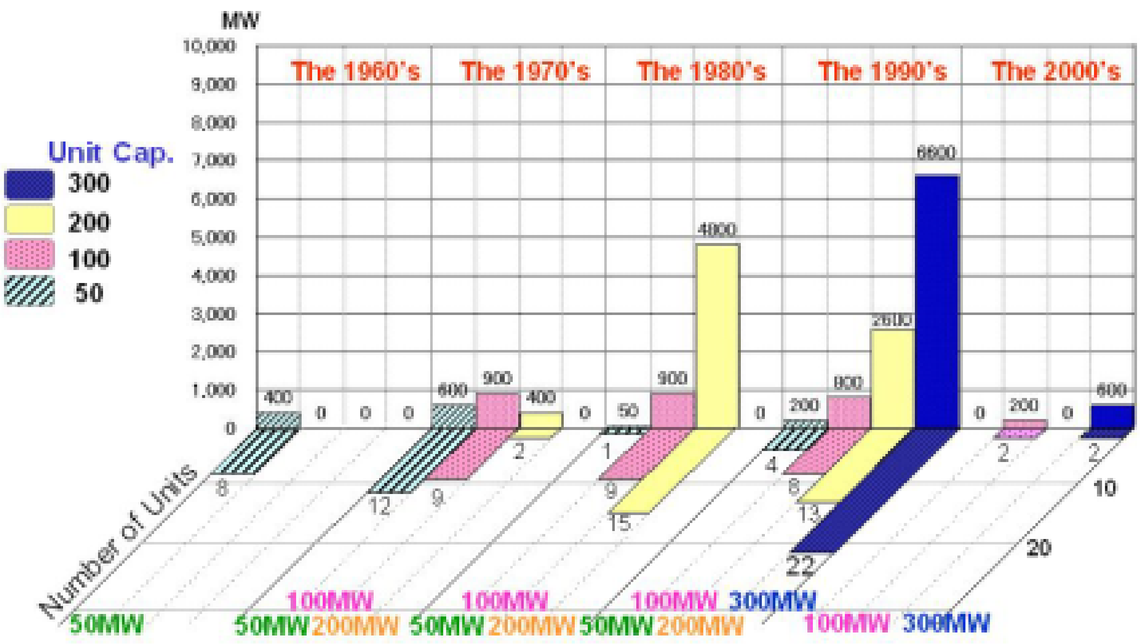

Fig.1(2) Installation Capability and Their Operating Years

(3) The Simulation concept (Refer to Fig. 1 (3) A, B)

We shall explain how to predict the potential for CO_2 reduction in North China, utilizing the limited information and data available to us, where 108 units with 17,620 MW of total electric power generating capacity, .

(3-1) Classification of the installations into three categories

Work for predicting emission reduction will begin with determining the objects of the research. From the perspective of the costs involved in reducing CO_2 emission, installations that would wind up operating less effectively must be eliminated from the target list; specifically, this applies to recently built 300MW and 200 MW units, as they are most likely operating with reasonably higher efficiency at present and there is no room to improve the efficiencies more.

The object of an effort to reduce CO_2 emission must be towards the existing electric generating units which are likely operating under condition of lower efficiencies and the units which will be newly constructed on basis of Chinese technologies in near future.

Basic idea for reducing CO_2 emission is shown on Table 1 (3)

Table 1 (3) Category of How to Reduce CO2 Technically

Category	Technology and Options of CO2 emission Reduction
● **Type-A** Existing units that have deteriorated to be replaced with more advanced units Technologies to be applied are---- **Baseline is ------**	Scrap and Build of **50 MW** coal fired units 50MW units □ Single 100MW or 200MW Japanese commercialized and advanced technologies. **Existing units** or **newly rebuilt units** designed on basis of Chinese technology.
● **Type-B** 100MW and 200MW Coal-fired Existing Units in Operation----- Improvement of Efficiency ------ Technologies to be applied to the Modification are ------- **Baseline**	Modification of boiler and steam turbines using Japanese commercialized and advanced technologies. (Not to convert coal to any others) Switching Burners to Advanced types, Technologies for more heat recovery. **Existing units** before the modification
● **Type-C** Mainly 600MW units in New Construction Plan in the 11th Five Year National Plan (Coal or Natural gas fired) Improvement of Efficiency by---- **Baseline**	Replacing Chinese design with Japanese commercialized and advanced type unit. ・Subcritical to Supercritical steam pressure ・Steam temperature commercialized in China to the most advanced level in the world. **Chinese commercialized design unit**.

Fig. 1 (3) A is an explanatory diagram of procedure simulating CO_2 emission reduction based on modification of the installation, Type-A and Type-B.

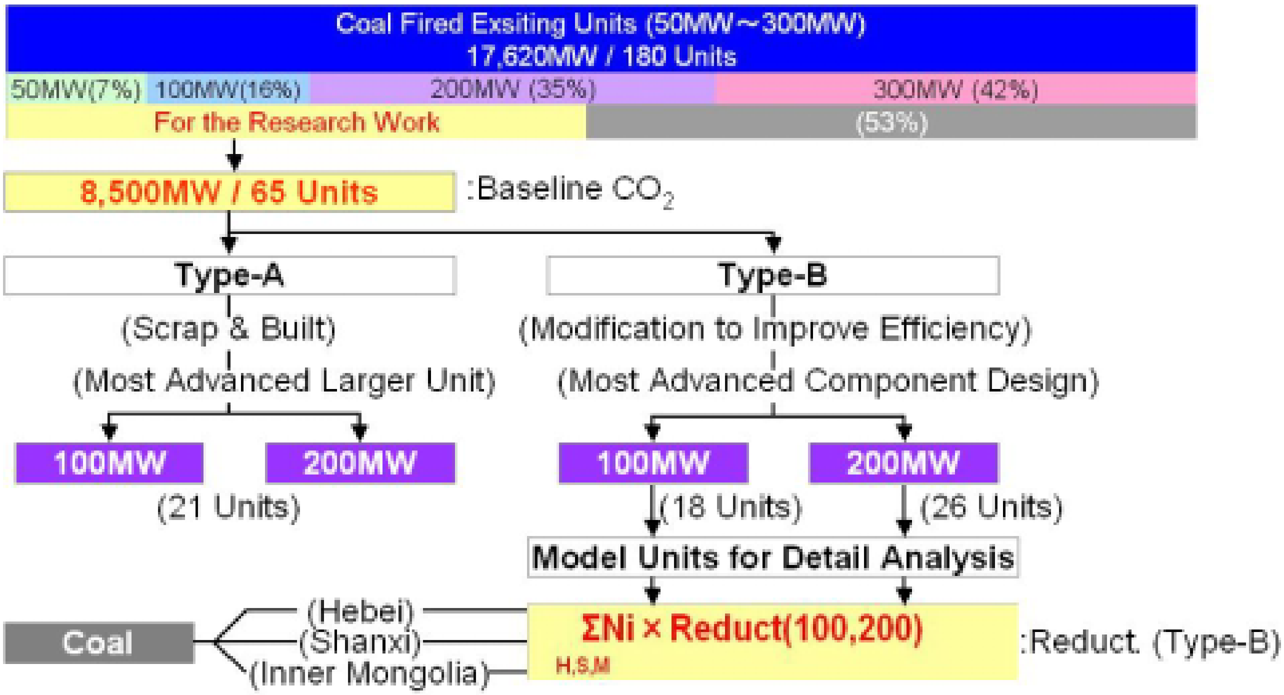

Fig.1(3)A Concept of the Simulation Method

(3-2) Procedure of Simulating CO2 Emission Reduction

We shall explain the procedure for the simulation work and related information and data needed for simulation. ｛ For " Information-K, B,D", refer to item (3-3) ｝

Step-1：Key Information

Collection of the **key** information **(Inf.-K)** on all electric power Generating units in North China. followed by site surveys to candidate nodel plants.

Step-2：Classification of the Existing Units into the Categories

Classifying the units into **Type-A** and **Type-B** on the basis of an investigation into **Inf.-K.**

Step-3：Baseline

① Selection of a model unit for each unit capacity group, 50MW, 100MW and 200MW in three regions each, Hebei, Shanxi and Inner Mongolia.
That is, a total of nine representative units for three kinds of capacities in three regions, each to be be selected.

②Collection and Survey of the **basic** information **(Inf.- B)** on the nine representative units in addition to **Inf.- K.**

③ Calculation of the baseline CO2 emission (ton/year) to be calculated on the basis of **Inf.- B** for all of **Type-A** and **Type-B** groups respectively.

Step-4：Technologies Matching for Type-A and Type-B Groups.

① For 50MW units, the appropriate technology for reducing CO2 is to replace the existing units with a smaller number of larger units, having greater efficiency, resulting in less CO2. emission.
For instance, four 50MW units will be replaced by one 200MW unit which can be operated with greater efficiency to generate the same amount of the power.

② For 100MW and 200MW units, a better solution is to modify boilers and/or steam turbines so that they can be operated with greater efficiency, resulting in less CO_2 emission .

Step-5：Selection of Three Model Units for investigation in detail

Selection of three models, one for 50MW (Type-A) and one for 100MW and 200MW each (Type-B) for the purpose of a detailed and precise technical investigation of CO_2 emission reduction.

Note：The numbers of the models to be selected and investigated in detail should depend on whether design specification and operation performance vary even more than they do in North China.

Step-6：Collection of detail technical and economical information on the nine model units (Inf.-D) including the Three Models.

Step-7：Detail analysis to reduce CO_2 emission on the Three Model Units

Detailed analysis here means precise calculation for predicting the potential of CO_2 emission on the basis of **Inf.-K, B, D** and **Step-4** for the individual model units.

Consequently, results of "detailed analysis" indicate the potential for CO_2 emission reduction specifically for the three model units representing 50MW, 100MW and 200MW respectively.

Step-8：Precise prediction of CO_2 emission reduction in North China

The Three Model Units investigated in detail can serve as representatives for the units of the same capacity as the models in the same regional groups.

CO_2 reduction possibility of the model units obtained through Step-7 can be deemed to represent the reduction potential in the group to which the model belongs.

In accordance with the above assumption, the CO_2 emission reduction potential for all of the three capacity groups, which are distributed over three regions, can be calculated with a minor error that may be due to some differences in original design and actual operation conditions.

(3-3) Technical Information required for the simulation (Detail of " Inf.-K, B and D ")

① **Key Information (Inf.-K)**

Number of units to be investigated：all units in North China (66 units / 21 power stations)

Information required

- Name of the electric power station
- Numbers and Unit Capacity consisting the electric power (Numbers × MW)
- Unit Availability (Annual operating hours at rated load equivalent)
- Year / Month of commercial operation commencement

② **Basic Information (Inf.-B)**

Number of units to be investigated： Nine units (From three power stations in three regions)

Information required：

- Major Specifications of Design (Steam temperature, pressure)
- Gross Power Generation Efficiency at Generator Rating (Throughput / heat input %)
- Electric Power Generated Annually (MWh / year)
- Coal Consumption (tons / year)
- Kinds of Coal Pulverizers (Vertical or horizontal shaft)

③ **Detail Information (Inf.-D)**

Number of units to be investigated：Nine units (From three power stations in three regions)

Information required concerning the units in Inf.-D ：

- Specifications of coal burnt in the nine units (Result of ultimate analysis, calorific value)
- Conditions and analysis of exhaust flue gas (temperature, oxygen content and carbon content in fly ash, etc)
- Auxiliary Power (pulverizers and fans in KWh / year)
- Economic Information
  Cost of construction, operation and maintenance)
  Fuel cost (Fuel coal and natural gas)
  Selling price of electricity generated and heat

(3-4) Technology to reduce CO2 and its Application

Table 1(4) is a summary of practical technologies for the three types and describes which units they will be applied to.

Table１（４）Technology to Reduce CO2 emission

Technology to be applied	Units the Technology is applied to
● **For Type-A** Replacement of the low efficiency units with superior units N×50MW ⇒ n×（100MW or 200MW） （"ｎ"is less than" N"）	N×50MW coal-fired units that began commercial operation before the 1970's
● **For Type-B** Modification to improve efficiency at the top loads and also part loads of the units. Recovery of exhausted flue gas heat Less air necessary for combustion Lower exhaust flue gas temperature Turbine rotor replacement with a more advanced model	100MW coal-fired units launched in the 1970's and the 1980's. 200MW coal-fired units launched in the 1980's and the 1990's
● **For Type-C** Japanese commercialized and cutting-edge 600MW and / or 1,000MW Steam pressure：24.1 Mpa Steam temperature：566 / 593 or 600 / 600 ℃ Plant efficiency：43.33% for 566 / 593℃	Chinese 600MW units planed in accordance with the 11th.Five Year Plan. Steam pressure：16.7 MPa Steam temperature：538 / 538 ℃ Plant efficiency：　41.44%

Improvement of plant efficiency means reduction of heat loss resulting in CO2 emission reduction.
Heat loss is found in various parts of the plant as shown in Fig.1(3)B.
Table 1 (3) describes practical method of reducing heat loss as well as its concept.

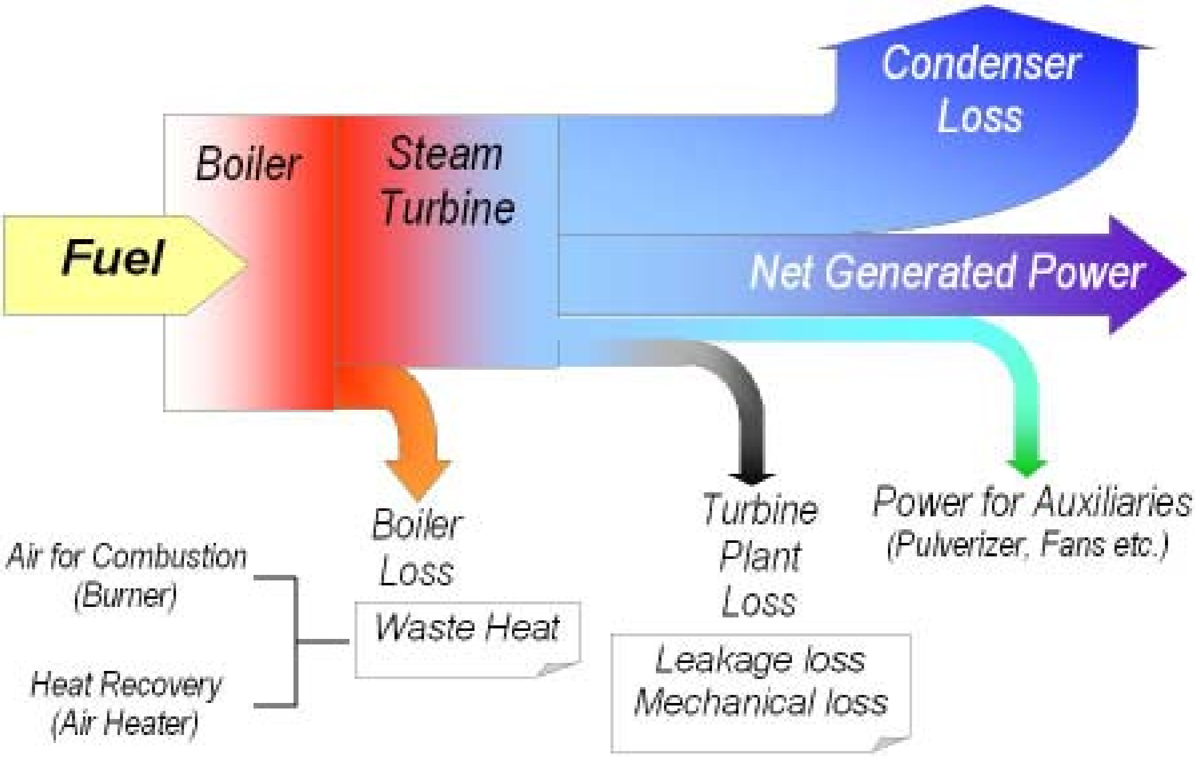

Fig.1(3)B Improvement of Power Plant Efficiency

Table 1 (3) CO2 reduction Technologies and Its application

Installation	Concept	Practical Method
Boiler Waste Heat Loss	More heat recovery	Burner replacement Reduction of air flow quantity for combustion Air heater modification or replacement Waste heat of exhausted flue gas is reduced Maintenance of Insulation Reduction of radiation loss
Steam turbine Loss	Reduction of Turbine internal loss	Replacement of rotating blade With advanced one.

System loss	To minimize steam leakage Loss reduction in part load operation	Maintenance of auxiliaries such as valves Application of variable or reduced pressure operation in part loads
Saving auxiliaries power	Replacement of main auxiliaries with better efficiency	Coal pulverizers and fans

2. CO2 Emission Reduction Potential

(1) CO2 Emission Reduction in Existing Units (Type-A and B)

(1-1) Baseline of CO2 Emission

Category	Unit Capacity MW	Region	CO2 Emission Rate (10- 6 ton/Kcal-Input)	CO2 Emission (ton / year)
Type-A	50	Hebei	0.378	3,321,000
		Shanxi	0.415	1,546,000
		Inner Mongolia	0.402	1,772,000
		Total	—	6,639,000
Type-B	100	Hebei	0.378	1,465,000
		Shanxi	0.415	7,419,000
		Inner Mongolia	0.402	3,357,000
		Total	—	12,241,000
Type-B	200	Hebei	0.373	12,393,000
		Shanxi	0.415	11,070,000
		Inner Mongolia	0.402	6,680,000
		Total	—	30,143,000
Grand Total				49,023,000

(1-2) Results of Investigation on CO2 Reduction for the Model Units

① Main Equipment (Efficiency Improvement of Boiler and Steam Turbine)

Model / CO2Reduction Technologies	Type-A 50MW Model Shanxi	Type-B 100MW Model Inner Mongolia	Type-B 200MW Model Inner Mongolia

Waste Heat Recovery Flue gas Temp. ℃ Excess Air Rate % Improve. of Efficiency % Relative Improve. Rate %	 150 ⇒ 140 37 ⇒ 15 88.65 ⇒ 90.68 2.30	 145 ⇒ 140 35 ⇒ 15 89.71 ⇒ 91.00 1.40	 155 ⇒ 140 28 ⇒ 15 90.73 ⇒ 92.22 1.60
Modification of Turbine Relative Improve. %	Replace.with100MW =23.60 Replace.with200MW = 27.90	1.50	1.50
Plant Efficiency Improve.% (Boiler + Turbine)	Replace.with100MW =25.90 Replace.with200MW =30.20	2.90	3.10

② **Major Auxiliaries (Power Saving of Pulverizer and Fan)**

China / Japan Auxiliaries	**Chinese normal**	**Japanese Standard**	**Relative Improvement(%)**
Power consumption Rate ● Pulverizer (KWh / ton-Coal) ● Fans(FDF and IDF) (KWh / ton-Air)	18 3.90	7.0～9.0 2.92	**50～60** **25**
Remarks	In average obtained from data available	—	—

(1-3) CO_2 Emission Reduction Potential for Type-A and B (Existing Units)
(Unit: 1000×ton-CO_2/Year)

Reduction \ Group	50MW	100MW	200MW	Total
Baseline CO_2 Emission	6,640	12,240	30,140	49,020
● Reduction in Main Equipment.	50 to 100MW ⇒ 1,720 50 to 200MW ⇒ 2,010	355	934	3009～3229
● Reduction in Major Auxiliaries ＊	132	169	336	637
● Grand Total	1,852～2,142	524	1.270	3,646～3,936

＊CO_2 emission reduction equivalent to the electric power consumption saving for the auxiliaries

Fig. 2(1) is summary of CO_2 emission reduction by Type-A and B and That due to saving auxiliary power in Power plants for 50MW,100MW and 200MW units.

＊ Not included: CO_2 reduction effects due to the power saving for the auxiliaries.

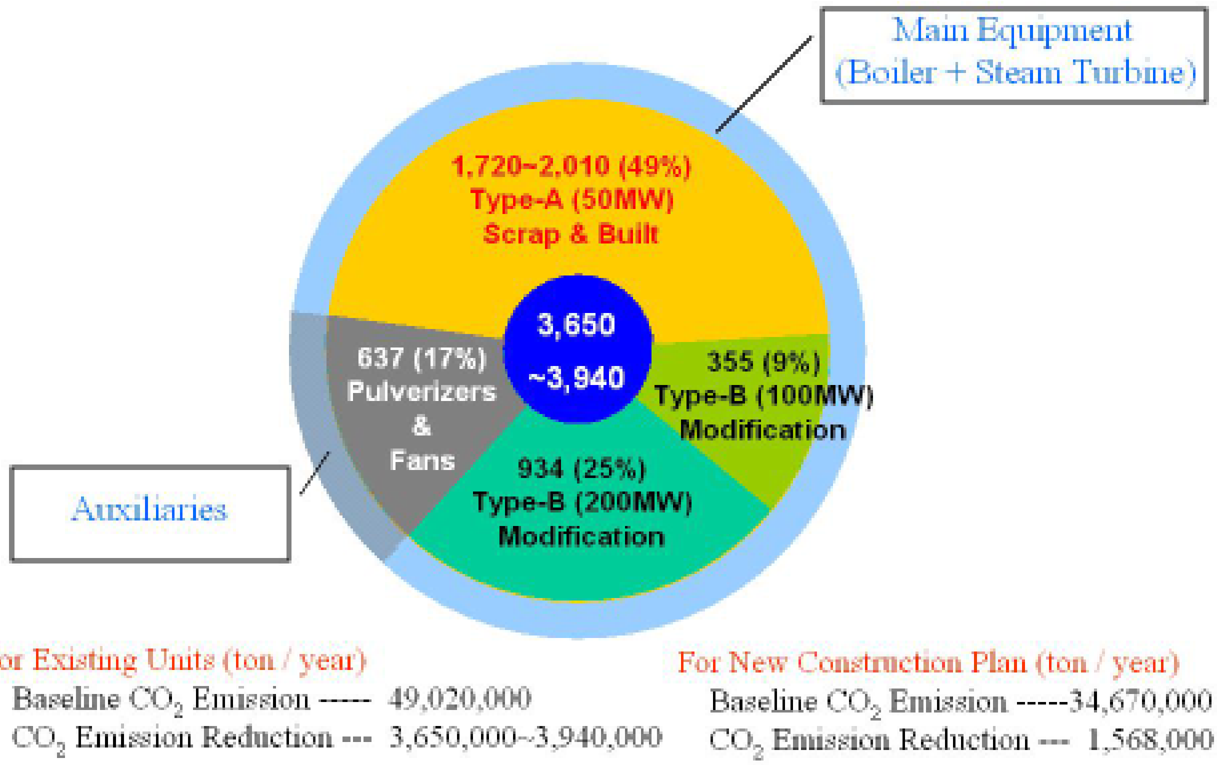

Fig.2(1) CO_2 Emission Reduction Method and its Effect

Power plant efficiency is greater for the higher steam temperature and pressure at the entrance of steam turbine.
An economical advantage for the power plant can be obtained for the larger unit capacity provided that tried-and-true technologies are applied to the plant.

3. Conclusion

(1) Prediction method of CO2 reduction

Electric power stations are generally scattered over a wide area, regardless of the country, and their design, such as unit capacity and efficiency, vary greatly.
Moreover, the installations have been maintained in various ways and with individual technologies since being brought into service.
This suggests that units may be operated under different conditions, even if they were built in roughly the same period.
It is therefore difficult and costly work to estimate the CO2 emission and its possible reduction for all installations in a specific region such as North China

It may be not practical to predict the total emission reduction by calculating such for one by one installation, because the analysis requires much technical information while it is not necessarily possible to collect all data; moreover, it may be time-consuming and costly undertaking.

We have developed a method to enable us to predict total CO2 emission reduction precisely and efficiently with less cost for a considerable number of power generation units in some specific region.

Application of the method so developed is not restricted to countries and regions, although it is limited to electric power industries that consist of steam generators and steam and / or gas turbines.

(2) CO2 emission reduction in North China

CO2 Emission Reduction / Category-Type	**CO2 Emission Reduction Potential (1000 ton /year)** (Except the specified)	Remarks
● **For the Existing units**		For the Objects
CO2 Emission at present	**49,023**	
・Main Installation		Boiler & Turbine
Type-A (50MW)	1,720～2010	
Type-B (100MW)	355	
Type-B (200MW)	934	
Total Reduction	**3,009～3,299**	
・Major Auxiliaries		Pulverizer & Fan
Type-A (50MW)	132	
Type-B (100MW)	169	
Type-B (200MW)	336	
Total Reduction	**637**	
Grand Total of CO2 Emission Reduction	**3,646～3,936**	
Reduction Rate based on " Baseline"	**7.4 %～8.0 %**	
● **For the Planning Units**		
CO2 Emission for the units China designed	**34,607**	
Type-C (New Construction Plan)		

CO2 Emission Reduction Possibility **Reduction Rate**	**1,568** **4.5 %**	

Appendix

—An expedient method of calculating CO2 emission from electric power generator—

Technical information required to calculate the CO2 emission amount precisely from power stations are, ① the data of coal analysis, ② power generation efficiency and □ amount of generated electricity amount.

During our present research work, we succeeded in collecting information in categories①,② and ③, for three kinds of unit capacities in three regions through Tshinghua University 3 E Research Institute.

In particular, the information in ① and ② is normally not available to outsiders, while ③ can be easily obtained only from a unit rating capacity and from annual operating hours.

We tried to extract a formula by which we can calculate CO2 emission amount by only taking into account ③ ignoring ① and ②.

To be exact, there is no expedient method that will give us a precise prediction for CO2 emission amount for any specific power station.
However the CO2 emission rate (ton-CO2 / MWh) shown below could be applied with a minor error for electric power generators having similar capacities anywhere in China, because the generation efficiencies and the coal specifications can be representative for almost all units in China.

Unit Capacity	Region	**CO2 Emission ton-CO2 / MWh**	Outline of Coal Specification
50MW	Hebei Shanxi Inner Mongolia	**1.012** **1.111** **1.077**	Coal in **Hebei** Calorie=5,260～5,510 Kcal/Kg Carbon in coal=52～59 %
	In Average	**1.051**	
100MW	Hebei Shanxi Inner Mongolia	**0.957** **1.065** **1.032**	Coal in **Shanxi** Calori=5,330～5,360 Kcal/Kg Carbon in coal=56～58 %
	In average	**1.042**	
200MW	Hebei Shanxi Inner Mongolia	**0.926** **1.065** **1.032**	Coal in **Inner Mongolia** Calorie=4,920～49,80 Kcal/Kg Carbon in coal=52～68 %
	In Average	**0.966**	