CHINA

Issues and Options in Greenhouse Gas Emissions Control

ENERGY EFFICIENCY IN CHINA: CASE STUDIES AND ECONOMIC ANALYSIS

SUBREPORT NUMBER 4

Prepared by:

A Joint Team from Clemson University and the Energy Research Institute, State Planning Commission of China

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FOREWORD

This report is one of eleven subreports prepared as inputs to the United Nations Development Programme (UNDP) technical assistance study, “China: Issues and Options in Greenhouse Gas Emissions Control,” supported by the Global Environment Facility and executed by the Industry and Energy Division, China and Mongolia Department of the World Bank.

This report is a joint effort of the State Planning Commission (including several ministries and research institutions) and the World Bank. It was prepared by a joint team of experts from the Energy Research Institute, State Planning Commission of China and Clemson University. The energy efficiency case studies that are the subject of this report were selected by international and Chinese experts, following the preparation of background reports on energy efficiency potential in China by experts from various Chinese ministries, research institutes, and universities (see *Energy Efficiency in China: Technical and Sectoral Analysis*, August 1994, Subreport 3.) A group of energy experts from China were trained in case study analysis at a workshop organized by SPC in Beijing in November 1992. Individual case studies were conducted between November 1992 and May 1993 by the Chinese case study team with the assistance of international consultants. Data analysis was completed over the summer and fall of 1993 by Chinese experts and international consultants at Clemson University. The final report was then prepared during 1994.

The report was drafted and edited by William A. Ward, Li Junfeng, James B. London, Dai Yande, Liu Jingru, and Gary J. Wells. The case study work was carried out by four groups: the data collection and analysis group included Li Junfeng, Dai Yande, Xu Ningnan, and Liu Jingru; the energy efficiency consultant group included Sun Yongguang, Zhang Jintong, Jiang Hanhua, Liu Dan, Sun Hongzheng, and Li Youhui; the senior advisory group including Shen Longhai, Zhou Fengqi, Zhu Liangdong, and Zhou Changyi, and; the sectoral analysis group. A complete list of participants is provided below.

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CURRENCY EQUIVALENTS

1 US$ = 4.7 Chinese Yuan (1990)

WEIGHTS AND MEASURES

ton of coal = 0.7143 tce, average
ton of crude oil = 1.43 tce
1000 m^3 of natural gas = 1.33 tce
Kilo(Watt) = 10^3 (Watts), Mega = 10^6, Giga = 10^9, Tera = 10^{12}

ABBREVIATIONS AND ACRONYMS

BOF	- basic oxygen furnace
CO_2	- carbon dioxide
EIRR	- economic internal rate of return
EEIRR	- environmental economic internal rate of return
FIRR	- financial internal rate of return
GEF	- Global Environment Facility
GHG	- greenhouse gas
GWh	- gigawatt-hour
kcal	- kilocalories
kgce	- kilogram of coal equivalent
kW	- kilowatt
kWh	- kilowatt-hour
LPG	- liquified petroleum gas
mtce	- million tons of coal equivalent
MW	- megawatt
NEPA	- National Environmental Protection Agency of China
NH_3	- ammonia
NO_X	- oxides of nitrogen
NPV	- net present value
SO_2	- sulfur dioxide
SPC	- State Planning Commission of China
t	- metric ton
tce	- ton of coal equivalent
TSP	- total suspended particulate
TVE	- township and village enterprise
UNDP	- United Nations Development Program

CONTENTS

PART 1 OVERVIEW OF CASE STUDY ANALYSIS

PART 2 ENERGY EFFICIENCY IN CHINA: CASE STUDIES

EXECUTIVE SUMMARY

i. The objectives of the study were: (1) to develop and evaluate cost-benefit methods for implementing the incremental cost principle within the greenhouse gases component of the GEF, and (2) to use those methods to analyse twenty-five industrial energy efficiency investments in China. The twenty-five projects that were studied can be divided into two major groups which in turn are subdividable into four subgroups:

Manufacturing Efficiency Project

- Fundamental enterprise restructuring projects, where the "energy efficiency project" constitutes a major rehabilitation investment for a large segment of the enterprise as a whole (M1 Steel: Openhearth to BOF Conversion; M2 Steel: Continuous Casting; CH1 Chemicals: Fertilizer Renovation; B1 Cement: Medium-Scale Kiln Renovation; B2 Cement: Conversion from Wet to Dry Process -- both Scenarios; and CH3 Chemicals: NaOH Membrane);

- Traditional energy conservation projects, where the project affects a small part of the enterprise (M3 Steel: Steel Rolling/Reheating Furnace Renovation; M4 Steel: Cogeneration/Blast Furnace Gas Recovery; CH2 Chemicals: Small Ammonia Plant Waste Heat Recovery; B3 Cement: Small-Scale Kiln Renovation; L1 Pulp & Paper: Cogeneration; T1 Textiles: Print/Dye Cogeneration; and T3 Textiles: Computerized Energy Management System);

- Combinations of the above, in which the project is too large to be considered "standard" but not large enough to constitute a restructuring (M5 Aluminum: Kiln Renovation; L2 Pulp & Paper: Black Liquor Recovery; and T3 Textiles: Caustic Soda Recovery).

Energy Consuming Equipment/Feedstock Improvements

- Projects whose effects will be felt by diffuse users of the good or service or in which the savings will be spread over a large number of applications (E1 High Efficiency Motors; E2 Variable Speed Motors; E3 Motor Repairs; E4 Steam Trap Production; C1 Coal Briquetting; C2 Coal Washing; P1 Low Voltage Line Loss; P2 Thermal Power Plant; and H1 Residential Buildings Energy Conservation).

ii. The 25 case studies considered herein reduce CO_2 emissions by 1.28 million tons per year (Table 5). In general, the projects have high rates of return on investment evaluated on financial, economic and environmental economic criteria. Twenty-four of 25 cases have financial and economic rates of return (FIRRs and EIRRs) above 12 percent, and 18 of the 25 cases have EIRRs above 20 percent (Table ES1). Part of these returns resulted from efficiency improvements in terms of energy per unit of output, while the remainder resulted from scale and output value effects of the projects on the affected enterprises. The output/value effects were adjusted out of the impacts before calculating the net cost per ton of GHG reduction (text Section IV, paras 4.3 and 4.4).

iii. After adjusting for output effects, 20 of 24 cases have positive net benefits per ton of CO_2 reduction as indicated in Table ES2.[1] These projects satisfy "no-regrets" criteria as the financial, economic and localized environmental health benefits retained within the Chinese accounting stance more than pay the costs associated with these alternatives for reducing emissions of GHGs. At face value, this outcome would suggest no "incremental costs" associated with these cases.

iv. When FIRRs are calculated in which the scale effect due to increased output is retained within the individual project enterprise, returns on investment for 16 of the 17 industrial firms for which this analysis is relevant exceeds 18 percent (with 10 of the 17 having FIRRs exceeding 25 percent). This implies that the absence of an investment subsidy to these sixteen enterprises to achieve the GHG emissions reduction seems not to be the critical factor constraining implementation of the projects.

v. Overall, 13 of 25 cases showed an increase in economic internal rate of return (EIRR) compared to the FIRR (Table 3). Two of the projects showed no significant difference between the EIRR and FIRR, and ten of the project EIRRs were below the respective FIRRs. However, only one of the projects has an EIRR less than 12 percent (the typical target rate of return for project analysis in China), while 18 of the 25 projects have EIRRs above 20 percent. Another three projects might be considered marginal, with EIRRs above 18 percent but below 20 percent. Only one of the projects "switches" from being unattractive to being attractive (greater than 20 percent IRR) with the imposition of economic prices as opposed to financial prices, while none of the projects switch to being unattractive when economic values are used. This analysis suggests that price reform is not the only issue constraining investment in the projects that were analyzed, and that moving to "free market prices" will not by itself lead enterprises to implement these energy efficiency investments. Instead, the price reforms must be combined with targeted interventions designed to identify and break the actual constraints that appear to impede efficiency improvements.

vi. For the most part, project rankings did not change drastically as the analysis moved from rate of return rankings to costs per ton of coal saved and per ton of CO_2 emissions reduction (Table ES3). Exceptions included M2 Continuous Casting, which showed low IRRs but relatively good cost effectiveness ratio calculations, and E3 Motors Repairs which experienced the opposite fate.

vii. Seven projects achieved substantial GHG reductions by restructuring the implementing enterprises. However, serious questions arose as to the ability of these

[1] The analysis also calculated net costs per ton of CO_2. These costs are project costs in the classic cost-benefit analysis sense. When discussing benefits and "costs" associated with GHG removal, this report will be referring to the net project benefits that are available to pay for GHG removal.

enterprises to finance the proposed projects (Table 8 and paras 7.21-7.24) and as to the financial sustainability of the post-project enterprises.

viii. The analysis of twenty-five case studies reported herein suggest the following conclusions:

- Enterprise viability should be a prerequisite for project financing, implying that the form of analysis used must not look only at model project analyses but also must analyze viability of enterprises within which the projects are proposed. This criterion is particularly critical for "restructuring" projects.

- Accounts derived from partial budgets should be used with great care in assessing energy efficiency and other efficiency-oriented project investments in enterprises particularly in formerly-planned and restructuring economic environments.

- In restructuring economic environments, the energy efficiency gains to be had from the structural and policy reform process likely will be much greater than those from a series of incremental investments in "standard" energy efficiency projects in enterprises which need restructuring.

- Neither price reform to drive financial prices towards economic prices nor Pigouvian subsidies to "internalize" the economic and environmental impacts into financial accounts will by themselves be sufficient to bring about the implementation of the technologies for energy efficiency improvements assessed as part of this project.

- Other interventions, including management reform, identification of actual constraints, and technical assistance must complement the pricing and structural reform process.

- Studies should be undertaken to determine the actual reasons for the failure to implement high-FIRR, efficiency-improving projects. These studies should be used to identify interventions that promote the use of technology that is economically efficient and environmentally benign.

Table ES1: Financial, Economic, and Economic/Environmental Rates of Return

Sector/Case Study		Financial IRR	Economic IRR	Econ/Env IRR
I.	Metallurgy			
	M1. Openhearth vs BOF Project	16.08%	15.71%	15.78%
	M2. Continuous Casting Project	18.63%	19.42%	19.44%
	M3. Steel Rolling/Furnace Project	35.90%	37.65%	37.66%
	M4. Blast Furnace Gas Recovery	28.21%	41.44%	42.27%
	M5. Aluminium Plant Renovation	84.31%	82.80%	82.92%
II.	Chemicals			
	CH1. Medium-sized Ammonia Project	19.50%	22.73%	23.04%
	CH2. Small Ammonia Project	71.39%	54.02%	55.77%
	CH3. NaOH Membrane Project	29.39%	32.48%	32.63%
III.	Building Materials			
	B1. Medium-Scale Kiln Renovation	15.45%	14.03%	14.18%
	B2. Wet to Dry Processing Project	19.15%	18.33%	18.43%
	B3. Small-Scale Kiln Renovation	35.19%	32.51%	33.06%
IV.	Pulp and Paper			
	L1. Co-Generation Project	28.51%	28.92%	29.23%
	L2. NaOH Recovery Project	24.57%	22.40%	22.41%
V.	Textiles			
	T1. Printing & Dyeing Co-Generation	37.56%	37.64%	37.82%
	T2. NaOH Recovery Project	57.94%	34.46%	34.59%
	T3. Computer Management Project	Pos. inf.	Pos. inf.	Pos. inf.
VI.	Electric Motors			
	E1. High Efficiency Motors Project	26.19%	25.90%	25.93%
	E2. Variable Speed Motors Project	15.56%	16.77%	NA
	E3. Motor Repairs Project	44.77%	47.69%	50.86%
	E4. Steam Trap Production	52.41%	52.76%	52.78%
VII.	Coal Processing			
	C1. Coal Briquetting Project	63.08%	63.44%	66.68%
	C2. Coal Washing Project	18.80%	18.88%	36.56%
VIII.	Power Distribution			
	P1. Low Voltage Line Loss Project	-0.46%	-0.46%	-0.27%
	P2. Thermal Power Plant Project	194.79%	249.64%	251.53%
IX.	Residential Buildings			
	H1. Energy Conservation Project	23.15%	23.76%	24.07%

Table ES2: COMPARISON OF PROJECTS BY FINANCIAL, ECONOMIC, ENERGY CONSERVATION, AND ENVIRONMENTAL BENEFITS

Sector/Case Study		Financial IRR[2]	Economic IRR	Net Benefits/ Ton Coal[3]	Net Benefits/ Ton CO_2
I.	Metallurgy				
	M1. Openhearth vs BOF Project	16.08%	15.71%	(59.18)	(204.66)
	M2. Continuous Casting Project	18.63%	19.42%	1,218.51	1,614.11
	M3. Steel Rolling/Furnace Project	35.90%	37.65%	152.34	270.96
	M4. Blast Furnace Gas Recovery	28.21%	41.44%	328.41	318.61
	M5. Aluminium Plant Renovation	84.31%	82.80%	437.88	691.03
II.	Chemicals				
	CH1. Medium-sized Ammonia Project	19.51%	22.73%	344.69	456.59
	CH2. Small Ammonia Project	71.39%	54.02%	28.47	37.71
	CH3. NaOH Membrane Project	29.39%	32.48%	685.55	908.13
III.	Building Materials				
	B1. Medium-Scale Kiln Renovation	15.45%	14.03%	(1.11)	(2.80)
	B2. Wet to Dry Processing Project	19.15%	18.33%	(244.04)	(481.74)
	B3. Small-Scale Kiln Renovation	35.19%	32.51%	92.24	128.06
IV.	Pulp and Paper				
	L1. Co-Generation Project	24.52%	28.92%	115.65	177.65
	L2. NaOH Recovery Project	24.57%	22.40%	647.58	188.31
V.	Textiles				
	T1. Printing & Dyeing Co-Generation	37.56%	37.64%	706.15	893.49
	T2. NaOH Recovery Project	57.94%	34.46%	867.21	1,148.76
	T3. Computer Management Project	Pos. inf.	Pos. inf.	851.10	1,127.42
VI.	Electric Motors				
	E1. High Efficiency Motors Project	26.19%	25.90%	246.66	2,438.48
	E2. Variable Speed Motors Project	15.56%	16.77%	NA	NA
	E3. Motor Repairs Project	44.77%	47.69%	29.97	70.49
	E4. Steam Trap Production	52.41%	52.76%	14,423.78	19,106.62
VII.	Coal Processing				
	C1. Coal Briquetting Project	63.08%	63.44%	80.22	113.66
	C2. Coal Washing Project	18.80%	18.88%	75.52	61.60
VIII.	Power Distribution				
	P1. Low Voltage Line Loss Project	-0.46%	-0.46%	(348.76)	(489.90)
	P2. Thermal Power Plant Project	194.79%	249.64%	463.90	749.69
IX.	Residential Buildings				
	H1. Energy Conservation Project	23.15%	23.76%	111.56	147.78

[2] Output adjustments were not made for the Financial and Economic IRR calculations.
[3] Output adjustments were made in calculating benefits (costs) per ton of coal equivalent energy savings and per ton of CO_2 emissions reductions.

Table ES3: Comparison of Projects by Financial, Economic, Energy Conservation, and Environmental Benefits (Technical Rankings)

Sector/Case Study		Financial IRR	Economic IRR	Net Benefits/ Ton Coal	Net Benefits/ Ton CO_2
I.	Metallurgy				
	M1. Openhearth vs BOF Project	22	23	22	22
	M2. Continuous Casting Project	21	19	2	2
	M3. Steel Rolling/Furnace Project	10	9	13	12
	M4. Blast Furnace Gas Recovery	13	8	11	11
	M5. Aluminium Plant Renovation	3	3	9	8
II.	Chemicals				
	CH1. Medium-sized Ammonia Project	18	17	10	9
	CH2. Small Ammonia Project	4	5	20	20
	CH3. NaOH Membrane Project	12	13	6	5
III.	Building Materials				
	B1. Medium-Scale Kiln Renovation	24	24	21	21
	B2. Wet to Dry Processing Project	19	21	23	23
	B3. Small-Scale Kiln Renovation	11	12	16	16
IV.	Pulp and Paper				
	L1. Co-Generation Project	16	14	14	14
	L2. NaOH Recovery Project	15	18	7	13
V.	Textiles				
	T1. Printing & Dyeing Co-Generation	9	10	5	6
	T2. NaOH Recovery Project	6	11	3	3
	T3. Computer Management Project	1	1	4	4
VI.	Electric Motors				
	E1. High Efficiency Motors Project	14	15	12	10
	E2. Variable Speed Motors Project	23	22	NA	NA
	E3. Motor Repairs Project	8	7	19	18
	E4. Steam Trap Production	7	6	1	1
VII.	Coal Processing				
	C1. Coal Briquetting Project	5	4	17	17
	C2. Coal Washing Project	20	20	18	19
VIII.	Power Distribution				
	P1. Low Voltage Line Loss Project	25	25	24	24
	P2. Thermal Power Plant Project	2	2	8	7
IX.	Residential Buildings				
	H1. Energy Conservation Project	17	16	15	15