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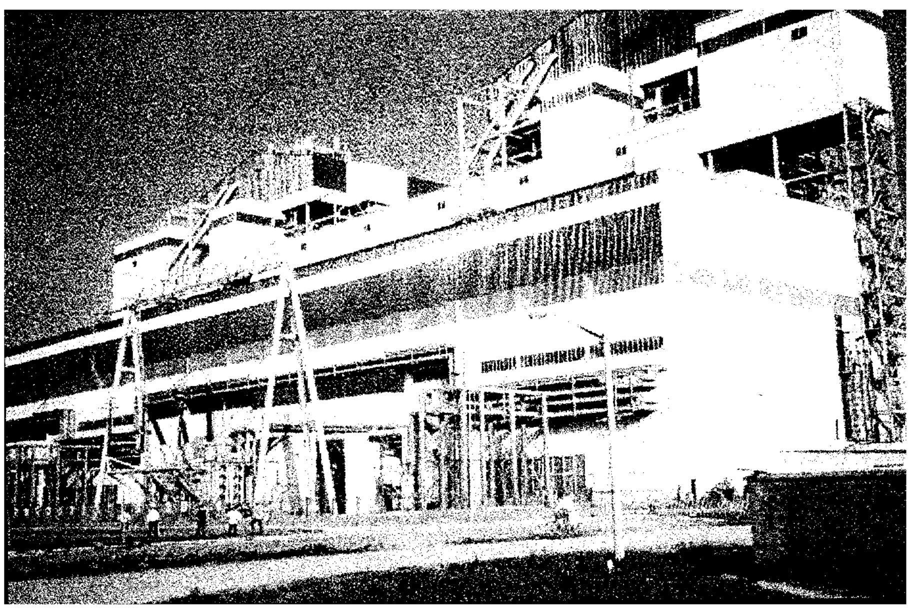

East Asia Environment and Social Development Unit
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FOREWORD

This report provides a comprehensive review of the environmental performance of Bank-financed coal-fired power plants in China since the mid-1980s. These results indicate that the Bank has played a catalytic role in improving the overall environmental performance of China's power sector. The report also identified issues associated with environmental assessments and implementing environmental management plans for these projects. Recommendations are provided at the end of the report.

This report is a joint effort of the East Asia Environment and Social Development Sector Unit (EASES) and the East Asia Energy Sector Unit (EASEG) of the World Bank Group. The site visits were coordinated by the Bank's China Resident Mission and was well received by China State Power Corporation and its branch power companies. The team also consulted China State Environmental Protection Administration (SEPA) and related local environmental protection bureaus during site visits.

The team thanks the Environmental Protection Office of the State Power Corporation, and in particular Mr. Wang Zhixuan, its Director, as well as each of the Provincial Power Corporations (Shandong, Shanghai, Zhejiang, Jiangsu and Henan) and staff of the individual plants for their hospitality and cooperation. In addition, the team thanks Nourredine Berrah, Principal Energy Specialist and Elaine Sun, Sector Coordinator for Energy in Beijing, for their support and continued encouragement.

William Gillen provided editorial assistance for this report. Ms. Ma Rui arranged the site visits for the team. The team thanks them and many others for making this report possible.

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ABBREVIATIONS AND ACRONYMS

BP	Bank procedures
CEM	continuos environmental monitoring
CO_2	carbon dioxide
EA	environmental assessment
EMP	environmental monitoring (or management) plan
EPBs	environmental protection bureaus
ESP	eletrostatic precipitator
FGD	flue gas desulfurization
GB	guo biao (Chinese) meaning national standards
gce	gram of coal equivalent
GP	good practices
GWh	gigawatt-hour
IGCC	integrated gasification combined cycle
kcal	kilocalories
kgce	kilogram of coal equivalent
kW	kilowatt
mg	milligram
mtce	million tons of coal equivalent
MW	megawatt
NEPRI	Nanjing Environmental Protection Research Institute
NM^3	normal cubic meter
NO_x	oxides of nitrogen
OD	operational directives
OP	operational policies
PIC	project implementation completion
$PM_{2.5}$	particulate whose diameter is no larger than $2.5*10^{-9}$ meters
PM_{10}	particulate whose diameter no larger than $10*10^{-9}$ meters
SAR	Staff Appraisal Report
SDPC	State Development Planning Commission of China
SEPA	State Environmental Protection Administration of China
S	sulfur
SO_2	sulfur dioxide
SPC	State Power Corporation of China
tec	tons of coal equivalent
TSP	total suspended particulate

TABLE OF CONTENTS

Appendices

EXECUTIVE SUMMARY

Background

Since the mid-1980s, the World Bank has assisted China in developing its electric power industry, financing not only large, new thermal and hydropower plants, but also transmission and distribution systems and renewable resources, as well as supporting policy initiatives to make the energy sector financially viable and environmentally sustainable. Since 1986, the Bank has financed approximately 9,000 MW of coal-fired power generation with an investment cost of approximately $ 9.4 billion, of which the Bank contribution was $ 2.9 billion. These plants were built to modern standards of operation and pollution control. Over this period, an evolution of environmental standards, guidelines and enforcement institutions has taken place both at the World Bank and in China. EASES reviewed these investments from a compliance perspective to determine if the Bank's investments in East Asia are environmentally sound.

Coal will continue to be the commercial fuel of choice in China for some time to come, with current use in the range of 1,100 Megatons annually, of which the power sector consumes roughly 25 percent. Based on this heavy use of coal by the power sector it has often been thought that much of China's urban air pollution comes from local power plants. However, research has shown most ground level air pollution comes from local sources. Nevertheless, over the last ten years, both China and the World Bank have enacted stricter performance requirements for the power sector, and modified their environmental assessment procedures to require environmental management programs as an integral part of all project designs.

Objective

The objective of this study was to assess environmental compliance of Bank financed coal-fired power plants in China to agreed Chinese and Bank environmental processes and standards. These requirements are articulated in the Environmental Management Plans (EMPs) which were included in the environmental assessments which were prepared during project preparation. The team visited Beilungang, Wujing, Zouxian, Yanshi, Yangzhou and Wai Gao Qiao power plants, spending approximately one to two days at each site.

Overall Impressions

The team was well received at most plants by well prepared environmental staffs. The team felt that environmental management was institutionally sustainable, supported financially by the local power company, and supported by the local community. The following general impressions describe the overall situation.

COMPLIANCE WITH STANDARDS

Most plants visited were in compliance with Bank environment standards as applied at the time of construction and initial operation. The more recent investments would be in compliance with most of the new Bank guidelines as well, primarily because they used high efficiency precipitators, low sulfur coals and improved design *and operation of effluent treatment facilities (see Figure A and B).*

Figure A Compliance of Particulate Emissions

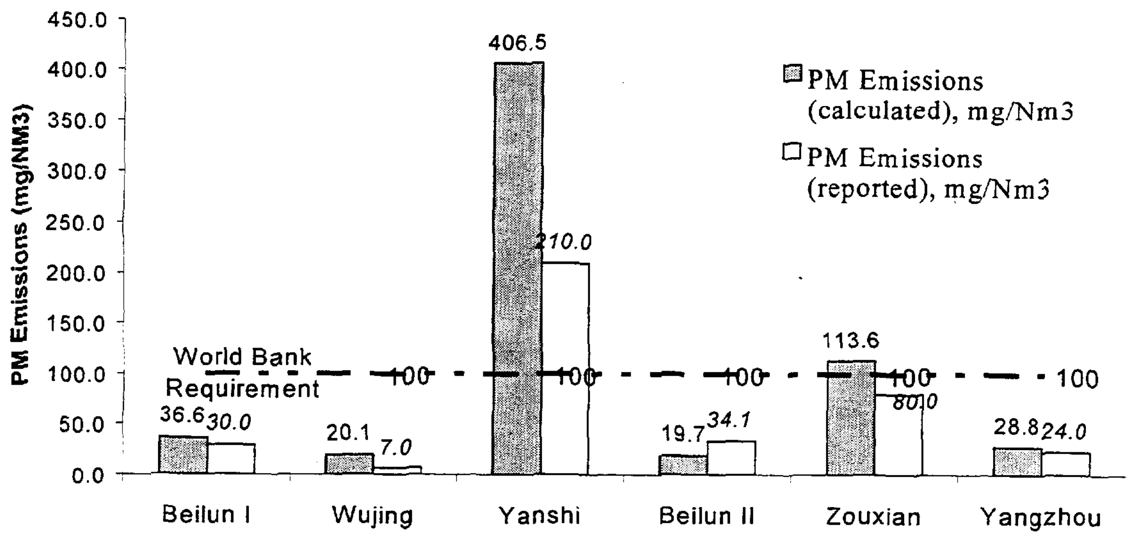
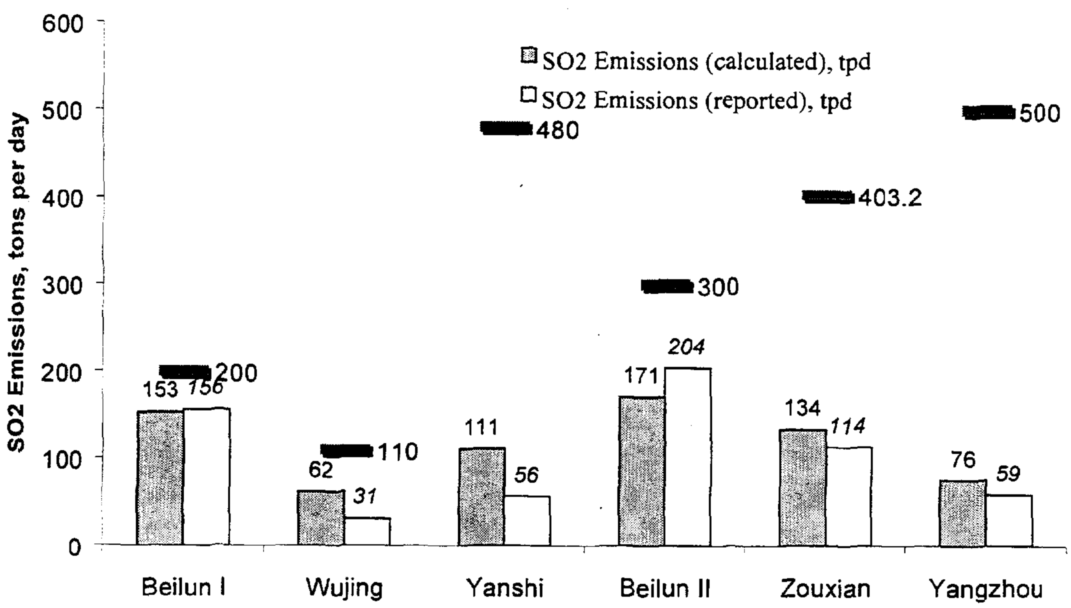


Figure B Compliance of Sulfur Dioxide Emissions



ROLE OF THE BANK

Bank involvement has been a catalyst in encouraging improved environmental management of overall plant operations including those operations not financed by the Bank (see Table A). In some cases, older units at some plants were retrofitted with precipitators which met Bank level standards. It is clear from a national perspective that the Bank's continued emphasis on environmental improvements, the use of more efficient power technologies and economic policy advice have led to a far more efficient power sector than would have been possible otherwise. Table A shows the leading performance in China's power sector.

Table A. Bank-Financed Plants Vs. Chinese Average

Average, g/kWh	Bank-Financed	Chinese Average
PM	0.22	42.3
Sulfur Dioxide	3.69	84.6
*NO_x**	1.57	42.3
Plant Efficiency	38%	33%

* There was no requirement on NO_x at the time when most of the plants were built

Boxes A and B highlight some positive impacts of the Bank's involvement in China's power sector.

Box A Technology Transfer

- First 600MW sub-critical unit in China;
- First super-critical 900/1000MW unit in China;
- Low NOx Burner
- Continuous monitoring equipment
- High efficiency ESP and FGD
- Tradable sulfur emissions pilot

Box B Institutional Impacts

- Preparation for power sector privatization
- Chinese environmental assessment procedures for power plants (HJT/T 13-1996) parallel with the Bank policies
- New national standards of China on ambient air quality includes requirements on fine particulate (PM10) control and requires more frequent sampling
- Chinese new emission standards include requirements on NOx and are explicit about adopting sulfur control measures if coal sulfur content higher than 1%

AGREEMENT WITH EA PREDICTIONS

Since operations began at these plants, there has been virtually no confirmation (measured) of predicted environmental impacts as described in the EA, particularly ambient air quality and thermal pollution from the discharge of cooling water. Generally, it is the responsibility of the local EPBs to measure ambient conditions. However, emissions and effluent water quality and noise are measured at the source required by the EMP.

All plants visited were well maintained. Plant staff were well qualified but it was clear that environmental management was not the major priority. Readiness to deal with and respond to environmental issues varied from plant to plant.

PUBLIC CONSULTATION

Major power station projects in China are subject to environmental review by State and Provincial authorities. The role of local EPBs in this process is virtually nonexistent, and as a result, their role was peripheral in managing and monitoring local conditions. EPB staff deferred to plant environmental staff for monitoring and laboratory analysis. The EA was not publicly available at the time of project preparation. The notion of making the EA available locally is still not widely accepted.

CONSTRUCTION IMPACTS

The EAs did not adequately address construction issues. Power projects require . long construction periods and significant irreversible impacts could occur. However, the EMPs did not, as a rule, provide any great detail regarding the construction phase. In some instances, this was completely absent.

ENVIRONMENTAL SUPERVISION

This review represents the first overall sectoral examination of environmental issues associated with the power sector. Environmental supervision heretofore by Bank staff has been minimal; however, the team believes that the situation would not have been more positive since Chinese power authorities looked after environmental affairs on their own.

Specific Observations

Emissions	• All plants met Chinese and World Bank standards for sulfur dioxide and nitrogen oxides emissions. In fact, most plants would have met new World Bank guidelines if they were in effect at the time of project preparation. • At several locations, plant management retrofitted older operating units with more efficient dust collection equipment, based upon their positive experience with the World Bank project. • At one plant, a low efficiency precipitator was specified, it appears to favor a Chinese contractor. Environmental standards for dust emissions out of compliance at this plant.
Liquid Effluents	Each plant has wastewater control systems in place and operating. Treatment systems meet local effluent standards. Incoming cooling water is often of lower quality than the effluent.
Ash Disposal	In some cases fly ash and bottom ash are used as construction material, depending on local construction needs. Where disposal is practiced, sites are well engineered and managed. They are often located far from the plant requiring the sluicing of ash laden slurry. More attention should be given to reducing the ash content of coals since disposal sites are expensive.
Coal Quality	In most cases, the coal specified in the project documentation is the coal being used. In some cases sulfur content may be lower, and in another case slightly higher. However, sulfur emission requirements are always met.
Safety/Emergency Preparedness	Safety and emergency equipment was available at most plants, especially on the machine floor near the turbine-generator.
Local EPBs	Local EPBs appeared to defer their responsibilities to plant environmental staff. Plant laboratories are better equipped than local EPBs. They noted that few complaints were registered either during construction or operations. A publicly available EA was still not recognized as appropriate but required by Bank procedures. EAs were not available to the local public.
Construction	The EAs and EMPs focus on plant operations and generally do not address construction, which can be a problem since these projects can take three to four years to construct, and may impact a large area.
Training	Too much overseas training was reserved for high level managers rather than for technical people who manage daily plant operations.

Recommendations

EXAMINE COAL QUALITY

As a result of analyzing data submitted at each plant, further work is recommended on the environmental and financial tradeoffs of improved coal quality. Specifically, the notion of using washed coal, resulting in improved heat rates producing less pollutants, needs to be reviewed carefully in light of tradeoff such as pollution created in the washing process.

ENHANCE THE ROLE OF LOCAL EPBS

The role of local EPBs in surrounding communities appears extremely limited. The team found that in most cases, the role of local EPBs in providing due diligence during construction and operations has been minimal. They often defer to power plant environmental staffs for sampling and self-reporting. In spite of generally good performance by the sector, there still exists the notion that environment is not a top priority but an issue to be addressed only when a crisis occurs. This view needs to be modified. The team recommends that there be new partnership between the EPB and environmental staff of the local power plant. However, this relationship must be based on the fact that it is the EPBs' responsibility to monitor environmental performance, report results to the local government body and assess damages for non-compliance.

INCREASE ENVIRONMENTAL SUPERVISION AND TECHNICAL ASSISTANCE

The team recommends that more effort be expended to supervise power projects. The Bank should continue to be engaged with China in improving power sector environmental performance. Involvement of the Bank is key to the further development of the sector, and to assisting the government in implementing private power.

ENHANCE SPC ENVIRONMENTAL CAPABILITY

Enhancing SPC environmental capability should be a top priority. Currently, the unit consists of five people who spend most of their time in Beijing. The team recommends that they develop a national power sector environmental database with SEPA. In addition, the unit should develop training capability to assist environmental staff of the various power plants.

IMPROVE ASH DISPOSAL

Ash disposal is reasonably well managed. Monitoring programs did not reveal any groundwater contamination at the plants visited. Since the coals used are fairly high in ash content (10 to 40 percent), large quantities of ash are generated. In most cases ash is slurried to large ponds located along rivers or hilly areas where the ash is used as fill or construction material. Reuse of ash should be increased if possible.

RATIONALIZE WATER POLLUTION REQUIREMENTS

Cooling water taken in by these plants is often of low quality, requiring treatment before it can be used in cooling systems. Yet the requirement is that it be discharged at a higher standard. It is monitored and if it does not meet the effluent standards, the plant can be fined, although incoming water is of lower quality. A more rational approach needs to be developed whereby these plants are not forced to treat their effluents to a higher standard than the available supply.

OPTIMIZING POLLUTION CONTROL

Additional work needs to be done to optimize pollution control for both emissions and effluents. Management of pollutants is driven by Chinese national standards and by Bank standards, regardless of ambient conditions. For example, the notion of tradable emissions is only now beginning to be considered. Market readiness is an issue although this approach has had some experience in Shanghai, but this needs to be refined and possibly extended to other parts of China.

ENHANCED PUBLIC PARTICIPATION

The EA and monitoring reports should be accessible to local stakeholders. Local EPBs should be more involved in environmental monitoring and enforcement.

EA DURING CONSTRUCTION

Power plant construction requires considerable time and substantial levels of manpower. As such, it is conceivable that permanent and significant impacts could occur. Yet EA documentation for construction aspects are exceedingly weak. Bank requirements for construction related issues, both in the EA and in the EMP, should be elaborated in detail. Specific guidance (a separate document outlining environmental management of construction sites) should be devoted to this issue.

AIR QUALITY IMPACTS ASSESSMENT

A considerable portion of the time and resources expended in EA preparation is devoted to collecting and analyzing air quality baseline data, and predicting air quality impacts. No one verifies these predictions; indeed it is nearly impossible, or at least extremely expensive, to do so. It is recommended that the Bank seriously review this requirement with the objective of developing alternative information requirements that can be secured in a shorter time and at less expense, and that provide nearly the same level of information regarding project-related air quality impacts.

1
INTRODUCTION

1.1 China's Power Sector

At about 1.4 billion metric tons of coal per year, China is the world's largest user of coal in the world. This figure continues to increase along with primary commercial energy consumption, which rose 5.4 percent per annum from 1980 to 1996. As the dominant fuel, coal accounted for 74.8 percent of total commercial energy production in China in 1996. The industrial sector is the largest consumer, accounting for 68.5 percent of final energy consumption. Recoverable coal reserves are estimated at 1,009 billion metric tons making it the clear energy source for some time to come.

Besides being the largest coal producer in the world, China is the second largest power producer in the world, after the United States. Between 1980 and 1997, both installed capacity and annual electricity generation grew at an average annual rate of about 8.9 percent, reaching 254 GW and producing 1134 TWh annually (see Appendix A). Since 1988, roughly 11 to 15 GW of generating capacity has been added annually. As a result, by 1997 most power shortages had been eliminated. Future investments in new generating capacity are expected to follow economic growth in general.

Of the total installed capacity of 254 GW as of 1997, roughly 76 percent burned fossil fuels, 22 percent came from hydropower and roughly two percent was nuclear. Although given high priority by the Government, hydropower development has so far been constrained by the distance between major hydro resources and primary load centers, generally exceeding 1,500 kilometers (km). In 1997, coal-fired power plants provided 82 percent of the total electricity generation of 1134 TWh. The share of oil-fired plants has been declining since the 1980s because of falling production in the country's aging oil fields. The slow pace of developing major gas supply sources, and the limited availability of natural gas, limited power generation from natural gas. Nuclear power, currently accounting for about 2.1 GW, is emerging as a significant source of energy.

China has 28 provincial and three municipal power grids. The Chinese government has been actively pursuing system interconnection to enhance the efficiency of the power system and to alleviate power shortages in the major load centers. China has adopted voltage levels of 500, 220, 110, 35, and 10 kV for its transmission and distribution systems. At the end of 1997, China achieved 130,169 circuit-kilometer (km) of transmission lines at or above 220 kV, and 293,870 megavolt-amperes (MVA) of transformer capacity at or above 220 kV.

Government restructuring in March 1998 resulted in the establishment of the State Power Corporation (SP), which replaced the former Ministry of Electric Power (MEP) following a one-year transition period. As a result, SP has emerged as the responsible agency executing power sector enterprise functions, under the supervision of the State Economic and Trade Commission (SETC), which is also responsible for the country's energy conservation program. The construction of new power plants and financing with external resources currently require the approval of the State Development Planning Commission (SDPC).

Financial institutions providing funds for power development include the State Development Bank (SDB), established in March 1994 and combining the six former investment corporations responsible for raising the necessary funding to fulfill the project requirements in six major sectors including the energy sector. SDB's role is to finance the national priority development projects and for projects in the inland provinces. The State Development Investment Corporation was established in August 1994 to take over the equity investment functions from the former sector investment corporations. China Construction Bank, along with other large state-owned commercial banks, now provides loans for power projects on commercial terms.

The other three important institutions in China's power sector are: (i) the Huaneng Group, a national-level power plant development corporation with several subsidiaries under SPC; (ii) the Sunburst Energy Development Corporation, a subsidiary of the China International Trust and Investment Corporation which is a leading non-bank financial institution in China with substantial interests overseas; and (iii) the recently-established China Power Investment Corporation.

Until the mid-1990s, the power sector was governed by a number of laws, administrative rules and regulations, and policy circulars, none of which were coordinated very well. Thereafter, the State Council approved a new Electric Power Law in December 1995, which became effective on April 1, 1996. This was a major step in making the legal and regulatory framework for the sector more transparent. Chinese government is now preparing a series of specific regulations, based on the broad guidelines of the Electric Power Law, which will replace the existing multitude of rules and regulations. The legal status of the power groups and companies, including their rights and obligations, is covered by the Company Law, which became effective on 17 July 1994.

1.2 The World Bank Thermal Power Lending Program in China

The World Bank financed nine coal-fired power plants in China since 1985 (see map). The first project was Beilungang #1. The most recent investment is Wai Gao Qiao Thermal Power Plant, which is currently under construction. The total capacity is approximately 9,000MW, and total investment is $9,413 million, of which $2,445 million came from IBRD. Detailed information is shown in Table 1.1.

MARCH 2000

IBRD 30470

Table 1.1 World Bank Thermal Power Plant Lending Program in China

No.	Name	Location	Date	Capacity (MW)	Investment	IBRD
1	*Beilungang I*	Zhejiang	May-86	600	$1,044.90	$225.00
2	*Beilungang II*	Zhejiang	May-87	600	$289.70	$165.00
3	*Wujing*	Shanghai	Feb-88	2*300	$354.10	$190.00
4	*Yanshi*	Henan	Dec-91	2*300	$459.60	$180.00
5	*Zouxian*	Shandong	Mar-92	2*600	$957.40	$310.00
6	*Beilungan II*	Zhejiang	Mar-93	2*600	$1,350.00	$400.00
7	*Yangzhou*	Jiangsu	Feb-94	2*600	$1,081.40	$350.00
8	*Tuoketuo*	Inner Mongolia	Apr-97	2*600	$1,300.50	$400.00
9	*Wai Gao Qiao*	Shanghai	May-97	2*(900 to 1000)	$1,898.00	$400.00
10	Leiyang	Hunan	Mar-98	2*600MW	$678.00	$300.00
	Total			10,200 to 10,400	$9,413.60	$2,920.00

The Bank's operational strategy in China is aimed at helping the country achieve economic growth in an efficient, equitable and sustainable manner. Accordingly, three strategic objectives -- efficiency improvement, environmental protection, and the promotion of growth in less developed inland provinces – comprise the Bank's operational focus in China. In the energy sector, the Bank's operational strategy supports the two-pronged energy development programs of Chinese government to expand energy supplies and promote energy conversion and end-use efficiency. The Bank is placing priority on the power sector in order to: (a) meet the growth in electric power demand, and (b) enhance energy efficiency and reduce adverse environmental impacts. Energy conservation in the industrial sector is an integral part of the Bank's operational strategy. The Bank is also helping the Government to develop more environment-friendly energy sources and facilitating the transfer of advanced pollution abatement technologies and development of clean coal power generation technology.

Because of the huge financing requirements of the power sector, the Bank will support the development of alternative methods of project financing, including foreign direct investment and co-financing arrangements. Continued support for the development of capital markets is expected to assist the Government in successfully mobilizing domestic resources for longer-term investment financing. The adoption of rational energy pricing and modern utility management practices, and power sector restructuring including divestiture, energy conservation, and environmental protection, will remain at the forefront of the Bank's energy sector policy agenda in China. Progress in addressing these policy concerns will create a more conducive environment for attracting private sector participation.

1.3 The Environmental Situation in China

The heavy dependence on coal for power generation is causing serious environmental impacts at every stage (extraction, transport, generation). Efforts are being made to reduce these impacts. In order to stabilize pollution discharge at 1995 levels, the Chinese government has set the following targets: (a) restrict discharge of dust (particulate) to 3.8 million tons annually through the use of electrostatic precipitators (ESPs) with average collection efficiencies of at least 98 percent for all coal-fired power plants of 6 MW or greater on any one grid; (b) restrict discharge of SO_2 by coal-fired power plants on any one grid to 6.5

million tons annually; (c) adopt low NO_x combustion technology for all new plants of 300 MW or greater; (d) ban discharge of coal ash into waterways and recycle at least 40 percent (45 million tons annually) of fly ash each year; and (d) 70 percent of wastewater from power plants must achieve national standards. Environmental protection is also being pursued through pricing reforms aimed at increasing cost-consciousness and by strengthening enforcement capabilities of provincial bureaus with environmental protection responsibilities.

Apart from the requirement that EAs have to be approved by the State Environmental Protection Administration (SEPA) for all new projects, the government is also trying to: (a) construct large scale thermal power plants with high heat rate, located at coal mine mouths, ports, and railway hubs; (b) retrofit or replace smaller thermal units (smaller than 50 MW per unit, and operated for more than 20 years) by larger, more efficient and less polluting plants; (c) improve the output and quality of coal by introducing advanced technologies for coal mining, beneficiation and washing, and (d) adopt clean coal technologies in existing and new power plants, such as high efficiency ESPs and flue gas desulfurization (FGD) systems. Several FGD projects are being implemented in areas where the sulfur content of coal is high.

The Government has launched a $2 billion program aimed at controlling the emission of sulfur dioxide over the next seven years, and is strictly enforcing an acid rain abatement program in several provinces and municipalities through the imposition of fines on sulfur dioxide emissions that exceed 1982 levels. The nationwide average collection efficiency of electrostatic precipitators utilized in coal-fired generating units in the PRC power networks is forecast to reach 97.5 percent during the Ninth Five-Year Plan, up from 85 percent in 1980. Considerable research is being done in the PRC on specific clean coal technologies such as integrated gasification combined cycle (IGCC) and pressurized fluidized bed combustion combined cycle. To reduce air pollution, such research and development projects are given high priority under the PRC's Agenda 21.

1.4 Origins and Objectives

The environmental assessment process has been under development in China for several years. Coverage and depth of analysis have evolved as shown in the improved quality of more recent EAs. The earliest EAs simply reported on a few aspects, such air quality, water temperature, liquid chemical effluent, and ash disposal. However, the latest EAs covered a much broader range of factors following OD 4.01 and the coal-fired power plant EA guidelines of the World Bank (Appendix E: the Bank's new guidelines on new and retrofitted thermal power plants).

Concurrently, the environmental regulation framework for coal-fired power plants also evolved gradually. In 1997, the latest version of environmental protection standards for coal-fired power plants were implemented. Even the latest EA did not fully consider such factors as i) environmental performance of plants operating under lower and unstable load rates; and ii) changing base line conditions such as coal quality and background pollution. In addition, it is now understood that preparing a good EA is not the same as having a environment-friendly coal-fired power plant.

Since the start of the Chinese program in thermal power plants supported by the World Bank, there has not been a thorough examination of their compliance with World Bank and Chinese environmental standards. This first examination will provide a review of this performance as well as point to ways to enhance it still further by looking at a broad range of issues that includes plant level operating procedures, coal quality and dispatching.

This review will examine:

- Evolution of the EA preparation process and environment standards for the power sector, both in the Bank and China, and the consequences;
- Environmental performance of Bank-financed power plants under operation, construction and preparation and compliance to the EMP;
- Lessons learned through the EA process and EMP implementation
- Impact of the Bank's EA process on the sector in general and in retrofitting older plants with modern pollution control systems; and
- The effectiveness and sustainability of the Bank's involvement in environmental aspects in the power sector.

The Team Members

2
EVOLUTION OF ENVIRONMENTAL REQUIREMENTS FOR THERMAL POWER PLANTS

2.1 The Environmental Assessment Process

Chinese and World Bank environmental requirements for thermal power stations are similar in that both incorporate a requirement for environmental assessment (EA), and both have adopted standards or guidelines for environmental performance. In addition, the World Bank has recently published its pollution prevention and abatement handbook 1998 as a companion to their official EA policy to offer guidance on types of issues normally considered when preparing a thermal power plant EA. The evolution of these requirements is discussed below.

CHINA

Environmental Assessment (EA) procedures in China have undergone gradual but significant changes in the last decade, paralleling to some degree the evolution of EA within the World Bank. The most current Chinese EA requirement is embodied in regulation HJT/T 13-1996. It may be difficult to directly link changes in the Chinese EA process to the specific evolution of the World Bank EA process. However, changes to the Chinese EA process bring it closer to that of the World Bank's, so there is no doubt about the World Bank's role in influencing the Chinese EA process for thermal power.

According to State Power Company officials, HJ/T 13-1996 borrowed many ideas from World Bank EA policies (OD 4.01). It focuses on new technology, public participation and actual protection of the environment (as opposed to the earlier Chinese EA procedures which concentrated on necessary mitigation to meet appropriate discharge standards). Officials also stated that they were looking to the World Bank for guidance in moving the EA process "upstream" in terms of preparing sectoral and regional EAs.

THE WORLD BANK

In 1989, the Bank adopted Operational Directive (OD) 4.00, Annex A: Environmental Assessment, and EA became a requirement for most Bank operations. The OD included important steps for incorporating environment considerations in World Bank project preparation. Significant aspects included: (a) a classification system for ranking projects in terms of their potential impacts; (b) a requirement for public consultation; and (c) specific scheduling for EA documentation to parallel the traditional project preparation cycle. The policy was amended as OD 4.01 in 1991 with some minor modifications. In 1998, as part of an overall World Bank effort to update and revamp its policies and procedures, OD 4.01 was modified, and reissued as OP/BP/GP 4.01. This last update provides increased detail for public consultation and reporting requirements, as well as explicitly linking environmental performance to the newly issued World Bank guidelines on pollution prevention and control (see discussion below). In every version of the World Bank EA policy, responsibility for preparation of EA documentation remains with the Borrower.

Generally speaking, under World Bank EA policies, a new coal-fired thermal power station would normally be considered "Category A", and as such would require preparation of an Environmental Assessment (EA). Guidance for the *type of issues* (e.g. flue gas emissions) to consider for the EA can be found in the Environmental Assessment Sourcebook. The Pollution Prevention and Abatement Handbook is used as guidance for the *levels of parameters normally considered acceptable for proper environmental performance* of the project (e.g. levels of dust, sulfur dioxide, and nitrogen oxides to be contained in flue gas emissions). Alternative levels for pollutant discharges are allowable, *but the EA must clearly demonstrate that no significant impacts to the human and/or natural environment would occur.*

An Environmental Management Plan (EMP) is also required as part of EA documentation. The EMP consists of five elements: (1) mitigation plan; (2) monitoring plan; (3) institutional strengthening plan; (4) implementation schedule; and (5) a description of institutional arrangements for environmental management. The EMP is critical in World Bank project documentation, because it reflects all necessary measures identified in the EA which must be taken to insure that a satisfactory level of environmental performance will be maintained throughout project life. Furthermore, *the World Bank EA policy now requires, as a loan condition, assurances by the Borrower to adopt and successfully implement the EMP. Thus the EMP becomes important leverage to guarantee proper environmental behavior by the Borrower.*

2.2 Standards and Guidelines

CHINA

Emission standards for coal-fired thermal power plants first came into force in 1992 (GB 13223-91). This regulation only considered emissions of particulates and sulfur dioxide for existing and modified plants. Standards were updated in 1997 (GB 13223-1996), and expanded to include emissions of nitrogen oxides. Under the updated standards there are three types of power plant depending on the date approval of construction was granted: Phase I, approved before August 1, 1992; Phase II, approved between August 1, 1992 and December 31, 1996; and Phase III, approved after January 1, 1997.

A comparison of the original standards and the more recent update for emissions (dust, sulfur dioxide and nitrogen oxides) from coal-fired thermal power plants are presented in Table 2.1 below.

Table 2.1 Chinese National Standards for Flue Gas Emissions for Coal-fired Power Plants

Pollutant	GB 13223-91				GB 13223-96				
	Plant Type				Phase				
	Existing Power Plant		New, Extended, Reconstructed Power Plant		I		II		III
	ESP	Other Dust Control	>670 TPH or Urban[2]	<670 TPH and Urban[2]	ESP	Other Dust Control	>670 TPH or Urban[2]	<670 TPH and Urban[2]	Urban or Rural
Dust (mg/Nm^3)	200-1000[1]	800-3300[1]	150-600	500-2000	200-1000[1]	800-3300[1]	150-600	500-2000	200-600[3]
Sulfur Dioxide -Mass flow (TPH)	-Correlation based on average wind speed, stack height				-Correlation based on average wind speed, stack height				
Sulfur Dioxide -Concentration (mg/Nm^3)	-				-		-		1200-2100[4]
Nitrogen Oxides (mg/Nm^3)	-				-		-		650-1000[5]

Notes:

[1] Range reflects ash content of coal: lower value < 10 per cent, higher value > 40 per cent with intermediate values specified in the regulation

[2] Value depends on both boiler size (coal feed rate in TPH) and/or regional character: urban vs. rural

[3] Range reflects regional character: lower value is urban area upper value is rural area

[4] Range reflects sulfur content of fuel: lower value is for coal containing > 1.0 per cent and higher value is for coal containing < 1.0 per cent

[5] Range reflects boiler type: lower value is dry bottom, upper value is wet bottom

As can be seen in the table above, requirements for the Phase I and Phase II plants are the same for both old and new regulations. However, for more recent plants (Phase III) the major improvements include: (a) dust emissions independent of coal ash content; (b) criteria for both mass flow and concentration of sulfur dioxide in the flue gas are included; and (c) nitrogen oxide emission standards are added.

The original standards proved effective in addressing particulate emissions; some 90 per cent of existing or upgraded plants as well as new ones had ESPs installed or retrofitted. However, to address the continuing deterioration of air quality with respect to sulfur dioxide and nitrogen oxide in many of China's large cities, the new standards include nitrogen oxide as well as requiring stricter controls on dust and sulfur dioxide.

Liquid effluent standards were established for all industries in 1988 (GB8978-1988) and modified in 1996 (GB8978-1996). For thermal power stations, liquid effluents are less of a problem than air pollutants. Major effluents from Chinese thermal plants include coal pile run-off, sanitary wastes, chemical wastes from the various subsystems (e.g. boiler blowdown) and cooling water. Typically, much of the cooling and chemical wastewaters are recirculated. Standards must be met without the aid of dilution.

Chinese effluent standards are linked to the classification of the receiving waters. Waters classified for drinking use have the strictest discharge standards, in comparison to waters classified for other uses. The Chinese standards do not specify allow temperature limits.

Solid Waste. In 1994, the State Economic & Trade Commission (SETC) published "Regulations on Coal Ash Management and Comprehensive Utilization". It specified in great detail acceptable solid waste management practices for coal-fired power plant ashes, including favorable policies and penalties associated with solid waste utilization.

Ambient air standards were promulgated in 1982 (GB 3095-82) and updated in 1996 (GB 3095-96). Standards include PM_{10} since epidemiological evidence suggests that much of the health damage caused by exposure to particulate matters is related to these fine particles. Ambient standards are established on the basis of air quality classification systems for the airshed in question (e.g. the location of any proposed thermal power station). A Class I area is a natural conservation district, resort, tourist area or region with historic monuments. A Class II area is normally associated with urban residential, commercial or rural areas. Finally, a Class III area is an industrial district or traffic center, etc. Table 2.2 presents a comparison of earlier and more recent Chinese air quality standards.

Table 2.2 Comparison of Chinese Ambient Air Quality Standards

	GB 3095-82			GB 3095-96		
	Airshed Classification			Airshed Classification		
POLLUTANT	**I**	**II**	**III**	**I**	**II**	**III**
***TSP*[1]**						
Annual average	-	-	-	80	200	300
Daily maximum	150	300	500	120	300	500
Once Maximum	300	1000	1500	-	-	-
Particulate matter < 10 μ						
Annual average	-	-	-	40	100	150
Daily maximum	50	150	250	50	150	250
Once Maximum	150	500	700	-	-	-
Sulfur Dioxide						
Annual average	20	60	100	20	60	100
Daily maximum	50	150	250	50	150	250
Once Maximum	150	500	700	-	-	-
Nitrogen Oxides						
Annual average	-	-	-	50	50	100
Daily maximum	50	100	150	100	100	150
Once Maximum	100	150	300	-	-	-

Note:
1 Total Suspended Particulates

Another significant advance in the new requirement (GB 3095-96) is the increased monitoring time-coverage for background air quality monitoring data. The original Chinese air quality monitoring protocol required:

- 4 monitoring campaigns per year (every three months);
- 5-7 days monitoring/campaign;
- Four six hour intervals/day; and
- 15-20 minutes of monitoring/interval.

At best, the original Chinese protocol provided monitoring data for 37.34 hours/year or a sampling window of 0.43 per cent, hardly a statistically representative sample. Since the World Bank required representative background information as part of its EA process (OD 4.01, Annex D, para. 7), for many Chinese power projects collection of baseline air quality data was a critical element in the preparation schedule.

Under the new monitoring requirements the sampling frequency was increased as follows:

SO_2/NO_x	TSP/PM_{10}
144 days/year	60 days/year
18 hours/day	12 hours/day
45 minutes/hour	45 minutes/hour

Thus the sampling window increased by almost a factor of 52 (SO_2/NO_x) and 14.5 (TSP/PM_{10}), respectively. Although the dust sampling window could be larger, these increases should provide more credible baseline data throughout the country. They will also remove this as a critical factor in preparation of thermal power projects financed by the World Bank or any other multi or bilateral development organization

Noise standards in China have been established for both major sources and levels at the plant boundary (GB 3095-93 and GB 12348-90). However, noise is not normally a major environmental issue for operation of thermal power plants.

Monitoring and Reporting. On April 26, 1996, Ministry of Electric Power Industry published "Regulations on Environmental Monitoring in Thermal Power Sector" to substitute several old guidelines on this matter. This document provided detailed requirements on the following:

- monitoring management structure, personal, and equipment;
- monitoring items, frequency, and method;
- monitoring regulation, management and reporting;
- budgets;
- appendix, including monitoring equipment, room space for monitoring stations.

Within six months of plant commissioning, the State Power Corporation required clearance of environmental performance of each plant. The clearance campaign is jointly organized by provincial environmental monitoring station and provincial EPB. The clearance report contains the following:

- Operation status of major equipment;
- Monitoring data, treatment, and summary;
- Mitigation methods and compliance;
- Comments and recommendations.

THE WORLD BANK

World Bank environmental guidelines first evolved from the late 1970s and were first formally compiled in 1984. There were no specific guidelines for thermal power stations, but rather a series of guidelines for emissions and ambient levels of dust, sulfur dioxide and nitrogen oxides, as well as guidelines for effluents (liquid discharges) and noise. Guidelines also discussed methods of control as well as procedures for sampling and analysis.

Emission guidelines for dust were based on concentration in the exit flue (mg/Nm^3), for *nitrogen oxides* on specific amounts generated per unit of fuel heat release (nanograms NO_x/joule heat input), and *sulfur dioxide* were based upon mass quantities of gas released per day (tons/day). Guidelines for dust and sulfur dioxide emissions were also dependent upon existing background levels.

In 1997, these Guidelines were revised. Separate guidelines were prepared for thermal power stations. Indeed, because World Bank membership increased to include countries from Eastern Europe and the former Soviet Union, separate guidelines were established for new power stations and rehabilitation of existing power stations. The new guidelines focus on discharges (gaseous, liquid, solids, and noise) from power stations. No ambient guidelines are provided. *It is important to note that all World Bank financed thermal power stations in China were subject to the 1984 Environmental Guidelines.*

A comparison of the World Bank Environmental Guidelines for air pollution associated with thermal power stations is presented in Table 2.3 below.

The chief water pollution problem associated with thermal power stations is heated water discharge. The 1984 Guidelines allowed for a discharge level 5°C higher than receiving waters if those waters were less than 28°C and 3°C if they were greater than 28°C. The 1997 Guidelines require a temperature rise of less than 3°C at the edge of the mixing zone. The updated Guidelines also set effluent limits on a variety of other water quality parameters (e.g. trace metals). Curiously, there is no association with inlet water quality.

Solid waste management is a key environmental issue in coal-fired thermal power stations. The 1997 Guidelines provide somewhat greater detail regarding how these materials should be managed.

Noise guidelines have been established in both the 1984 and the 1997 Guidelines. The general noise recommendations provided in the 1984 Guidelines varied from 45-55 decibels for the day-night average equivalent sound level. Value depends upon nearby land use. The updated Guidelines are approximately the same. Noise is not normally a major environmental issue for operation of thermal power plants.

Monitoring and Reporting: The 1984 Guidelines do mention the need for monitoring and reporting, and focus on pollutant sampling and analyzing methods. However, no comprehensive monitoring and reporting plan was required. The 1997 Guidelines provide more detailed requirements for pollutant monitoring and reporting.

Table 2.3 Comparison of World Bank Environmental Guideline For Air Pollution Associated With Thermal Power Stations

Pollutant	1984 Guidelines	1997 Guidelines[2]
Dust		
Emissions (mg/Nm^3)	100-150[1]	50
Ambient ($\mu g/Nm^3$)		
Daily Maximum	500	-
Annual Average	100	-
Sulfur Dioxide		
Emissions (Tons/Day)	100-500[1]	0.2/MW_e for first 500 MW_e 0.1/MW_e for subsequent capacity (Maximum 500 Tons/Day) and <2000 mg/Nm^3
Ambient ($\mu g/Nm^3$)		-
Daily Maximum	500	-
Annual Average	100	
Nitrogen Oxides		
Emissions (nanograms/Joule)	260 (lignite) 300 (coal)	260 (coal) 1500 (low volatile coal)
Ambient ($\mu g/Nm^3$) Annual Average	100	-

Notes:

1 Allowable value depends on ambient levels; the lower the ambient level the higher the allowable emission level

2 Updated World Bank guidelines do not provide ambient values.

3

ENVIRONMENTAL PERFORMANCE OF WORLD BANK-FINANCED THERMAL POWER PLANTS

3.1 COMPLIANCE WITH ENVIRONMENTAL MANAGEMENT PLANS

Most power stations visited complied with either the EMP or descriptions presented in the SAR with minor exceptions. In some cases, differences were plausibly justified. In a few cases there were clear inadequacies that should have been addressed during supervision. These issues are discussed below for each power station visited.

Table 3.1 shows basic information for each plant being visited (Wai Gao Qiao is not included).

Table 3.1 Basic Power Plant Information

Basic Information	Beilun I	Wujing	Yanshi	Beilun II	Zouxian	Yangzhou
Unit Capacity, MW	600	300	300	600	600	600
Unit number	2	2	2	3	2	2
Stack Height, m	240	210	240	240	240	240
Ash Content, %	14.7%	7.9%	30.6%	15.5%	22.4%	10.9%
Sulfur Content, %	0.85%	0.62%	0.81%	0.63%	0.70%	0.36%
Heat Value, kJ/kg	22966	22474	17201	22404.8	22535	21610
ESP Efficiency, %	99.80%	99.80%	99.20%	99.90%	99.60%	99.80%
Heat rate, gce/kWh	307	332	350	300	320	337
Plant Efficiency, %	40.1%	37.1%	35.2%	41.0%	38.4%	36.5%
Flue gas volume, Nm3/kg(coal)	8.0381	7.8659	6.0203	7.8417	7.8873	7.5635
Coal consumption, tpd	11265	6224	8573	16925	11966	13141

Overall summary tables presented in Table 3.2 - 3.5 show the specific emissions of SO_2, TSP and NOx. Based on these tables, the team found all plants met Chinese and World Bank standards for sulfur dioxide and nitrogen oxides emissions. In fact, most plants would have met new World Bank guidelines if they were in effect at the time of project preparation. At several locations plant management retrofitted older operating units with more efficient dust collection equipment, based upon their positive experience with the World Bank project. At two plants environmental standards for dust emissions were violated. At one, a low efficiency precipitator was specified, it appears, to favor a Chinese contractor.

Table 3.2 Compliance of Particulate Emissions
Unit: mg/Nm^3

PM Emissions	Beilun I	Wujing	Yanshi	Beilun II	Zouxian	Yangzhou
Calculated[1]	36.6	20.1	*406.5**	19.7	*113.6**	28.8
Reported[2]	30.0	7.0	*210.0**	34.1	80.0	24.0
Chinese Standard	300	150	400	200	300	200
World Bank Old Standard	100	100	100	100	100	100
World Bank New Standard	50	50	50	50	50	50

Note: *Non Compliance with SAR

1. Based on the basic power plant information, calculated with thermal balance theory (below is the same)
2. Based on survey forms and on-site interviews (below is the same)

Table 3.3 Compliance of Concentration Based Sulfur Dioxide Emissions
Unit: mg/Nm^3

SO_2 Emissions	Beilun I	Wujing	Yanshi	Beilun II	Zouxian	Yangzhou
Calculated	1692	1261	*2153**	1285	1420	762
Reported	1392	619	849	890	956	383
Chinese Standard	2100	2100	2100	2100	2100	2100
World Bank Standard	2000	2000	2000	2000	2000	2000

Note: *Non Compliance with SAR

Table 3.4 Compliance of Sulfur Dioxide Emissions
Unit: tons per day

SO_2 Emissions	Beilun I	Wujing	Yanshi	Beilun II	Zouxian	Yangzhou
Calculated	153	62	111	171	134	76
Reported	156	31	56	204	114	59
Chinese Standard	147	400	421	220	249	517
World Bank Old Standard	200	110	480	300	403	500
World Bank New Standard	170	75	70	180	120	170

Table 3.5 Compliance of Nitrogen Oxide Emissions
Unit: ppm

NO_x Emissions	Beilun I	Wujing	Yanshi	Beilun II	Zouxian	Yangzhou
Reported	237	225	257	253	200	212
Chinese Standard	317	317	317	317	317	317
World Bank Old Standard	417	417	417	417	417	417
World Bank New Standard	365	365	365	365	365	365

Table 3.6 shows that the environmental performance of Bank-financed thermal power plants is much better than the Chinese average (power plants not financed by the Bank), which demonstrates the positive impact of Bank involvement in China's power sector.

Table 3.6 Summary of Emissions
Unit: g/kWh

	Beilun I	Wujing	Yanshi	Beilun II	Zouxian	Yangzhou
PM						
Calculated	0.115	0.068	1.457	0.061	0.372	0.099
Reported	0.094	0.024	0.753	0.105	0.262	0.083
Bank-Financed Average	0.22	0.22	0.22	0.22	0.22	0.22
Chinese Average	42.30	42.30	42.30	42.30	42.30	42.30
SO_2						
Calculated	5.32	4.29	7.72	3.95	4.65	2.63
Reported	5.42	2.13	3.90	4.72	3.95	2.03
Bank-Financed Average	3.69	3.69	3.69	3.69	3.69	3.69
Chinese Average	84.60	84.60	84.60	84.60	84.60	84.60
NOx,	1.53	1.57	1.89	1.60	1.35	1.50
Reported						
Bank-Financed Average	1.57	1.57	1.57	1.57	1.57	1.57
Chinese Average	42.3	42.3	42.3	42.3	42.3	42.3

Over the period of interest (1988 to 1998), specific emissions have been attenuated by improved controls and management. A brief comparison of actual power plant performance with commitments made in Bank project documentation is presented in Table 3.6. Comparisons were made with either descriptions presented in the SAR (earliest projects) or with the EMP when it later became part of World Bank policy.

ZOUXIAN

Zouxian management honored their environmental commitments in a professional manner. Although coal purchase policies in China had changed since the time the project was designed, the plant maintained actual coal purchases of 0.5% sulfur coal as required in the SAR.

Ash sluice waters were to be entirely recirculated. However, a small amount (10M^3/day) is discharged. No adverse impacts have resulted.

All other items of the EMP either met or exceeded the SAR requirements. Of particular note was the special program undertaken at Nanjing Environmental Protection Research Institute (NEPRI). This program successfully met all of its objectives in: (1) establishing criteria for power plant siting in China's coastal areas based upon air quality impacts; (2) establishing NEPRI as a center for excellence in air quality modeling (physical and mathematical); and (3) establishing NEPRI as a center for excellence in testing and evaluation of flue gas desulfurization schemes.

Wai Gao Qiao

Construction on this project has not started, so many of the items indicated in the EMP have not been implemented as yet. However, all requirements of the mitigation plan have been introduced into either the design, bid documents or contracts. No monitoring equipment purchases have been made and no training programs have been initiated, but no modifications to the requirements as presented in the EMP are felt necessary.

It is of interest that Wai Gao Qiao management has gone considerably beyond mitigation commitments specified in the EMP. They have prepared detailed requirements for mitigation during the project construction phase, when in fact there are no such requirements in the EA approved by both the World Bank and the Government of China.

An environmental unit headed by a professional engineer is planned. Monthly data summaries will be sent to management (environmental office of the Shanghai Municipality Electric Power Company, SMEPC), who in turn will send it to the Shanghai Municipality Environmental Protection Bureau. Any required investments less than 500,000 RMB will be decided by power station management directly. For larger investments, a proposal will be prepared and submitted to SMEPC for consideration.

Beilun I

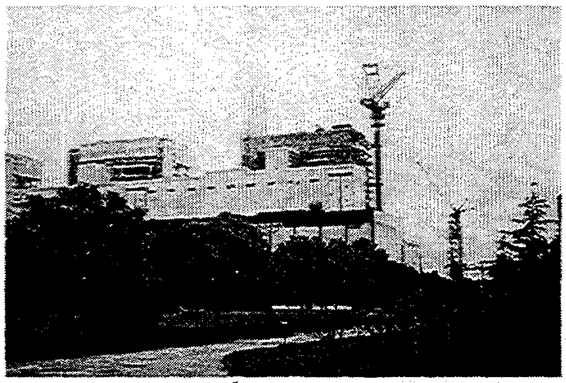
This was the first thermal power project financed by the World Bank in China. There are no outstanding difficulties; the project met or exceeded the commitments for mitigation and monitoring as presented in the SAR.

The plant level environmental group consists of six staff members reporting to the plant director. Any mitigation actions are prepared by the group, checked by the technical department and submitted to the plant director. For minor actions, the plant director decides what has to be done, and for major actions the proposal is submitted to the Zhejiang Power Company for action.

Beilun II

This project is currently under commissioning, so comparisons are made between recommendations presented in the EA and those reflected in the plant design/ bid documents/ contracts. As was the case with Beilungang I, this project meets or exceeds requirements presented in the EA. No discussions took place concerning commitments for monitoring equipment purchases, training and special studies.

Picture 1   Beilun Power Plant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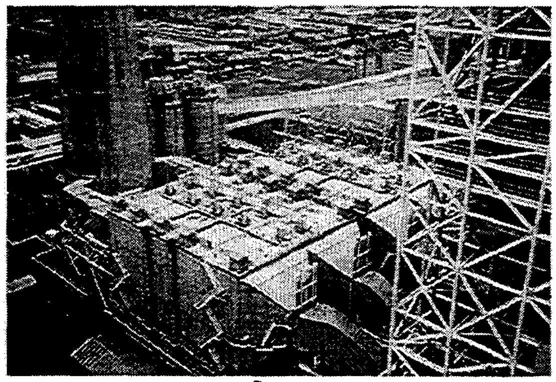
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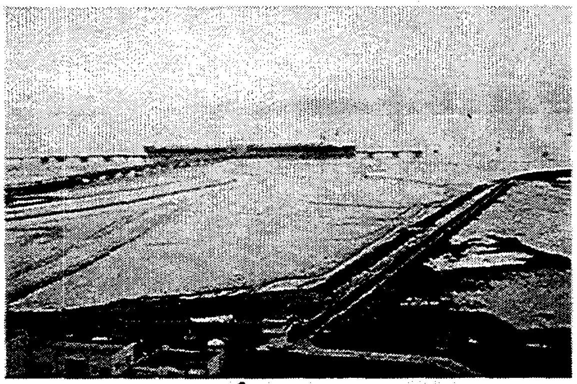
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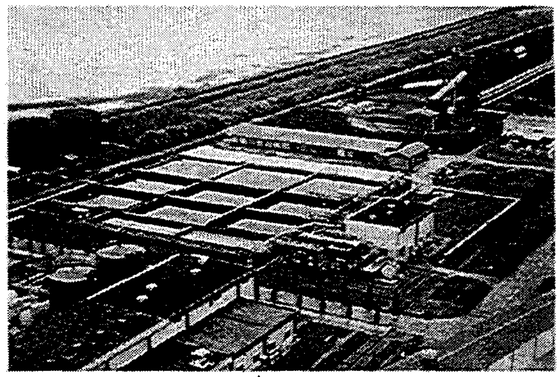
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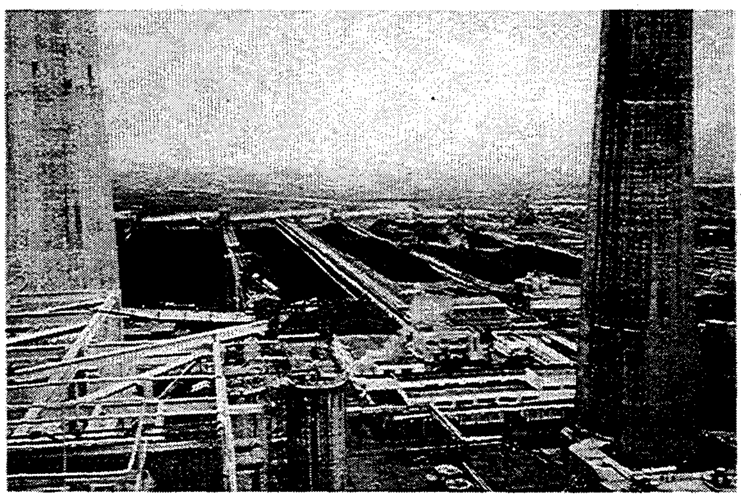


1. Whole Plant; 2. ESP; 3. Seashore Ash Pond;
4. Waste Water Treatment; 5. Coal Handling

Table 3.6 Summary of Environmental Compliance

ITEM	POWER STATION						
	Zouxian	**Wai Gao Qiao (Not yet built)**	**Beilungang I**	**Beilungang II (Under commission)**	**Wujing**	**Yangzhou**	**Yanshi**
Mitigating Measures	• Coal sulfur content same as SAR/ SO_2 emissions comply with EMP • Small discharge of ash sluice water • Some ash reused (+)	• Nothing specified for construction. Plant developed their own • All specifications included in design/bid documents/ contracts	• SAR described wastewater treatment and discharge into Jiantang Strait. • Actual 84% recycled, discharged remainder meets PRC standards	• All specifications adopted in design or specified in bid documents or constructed (clustered chimney)	• SAR recommended replacement of existing 80 meter stack with 150 meter stack-actually replaced with 120 meter stack • All emissions better than SAR specifications • SAR recommended 50% ash utilization-actually 100 %	Most mitigating measures same or better than SAR descriptions, except no watering of ash disposal sites or tree planting	Most mitigating measures same or better than SAR descriptions, except: ESPs had lower than specified efficiencies (ESPs were purchased locally, and should have been purchased internationally)
Monitoring Program	Groundwater done by local EPB, all other items as specified in SAR	Nothing yet implemented, no changes deemed necessary	Meets or exceeds SAR specifications	Same parameters, frequencies planned meet or exceed EA specifications	Monitoring program unavailable for review	Several elements are not implemented in accordance with SAR	Most elements same or better than defined in EMP.
Monitoring Equipment Purchases	All items specified were purchased Costs exceeded SAR estimates	Only CEM purchased to date	Nothing specified in SAR	Not discussed	Nothing specified in SAR	Equipment not secured as agreed include: • Air quality • BOD • Electric field • Mobile van	All purchases made except polarograph which was deemed unnecessary
Training	All training specified was met or exceeded	Nothing yet implemented, no changes deemed necessary	Nothing specified in SAR	Not discussed	Nothing specified in SAR	17 staff months in SAR 7 staff weeks received. Two trainees, one switched jobs after training	EMP lacked specifics. Comprehensive training implemented
Special Studies	All institutional development objectives at NEPRI were met	NA	NA	Not discussed	NA	NA	NA

Wujing

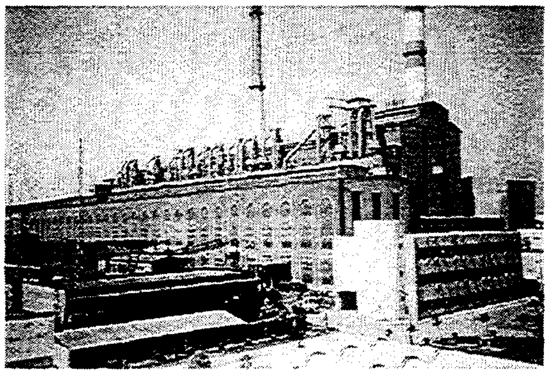
For the most part, mitigating measures implemented at the Wujing Thermal Power Station meet or exceed specifications described in the SAR. Of particular note is the use of low NO_x burners when they were not specified in the SAR and 100% reuse of fly ash rather than the 50% utilization rate described in the SAR. One major shortfall is in the replacement of the 80 meter stack on the existing units. A new stack of 150 meters was to be constructed, but the new stack installed was only 120 meters. No air quality monitoring was conducted to determine if this shorter stack was problematic.

Positive experiences gained with high performance dust removal equipment under the World Bank project encouraged Wujing management to retrofit their older boilers with high efficiency dust removal systems. Plant officials felt that the World Bank involvement also helped them focus on wastewater management. Wujing now represents a provincial model for zero discharge.

The SAR noted that at negotiations Shanghai Municipality Electric Power Bureau (SMEPB) agreed to implement a monitoring program satisfactory to the World Bank. Wujing officials were unable to produce this plan, claiming it is filed at SMEPB. If such a plan exists it should be on the plant premises as a working document and not buried in headquarters files.

The plant has two full time environmental staff responsible for the entire facility. Air quality monitoring is done by consultants and water quality monitoring is done in house. All data are reported to SMEPB and the Shanghai Municipality Environmental Protection Bureau on a monthly basis. If there is a problem, consultants are hired to determine how they should be resolved. If the costs are small the power plant takes care of it in-house. If there is a large problem the Production and Technology Unit prepares a proposal which is reviewed and approved by the Director, and then sent to SMEPB for further action.

Picture 2 Wujing Power Plant



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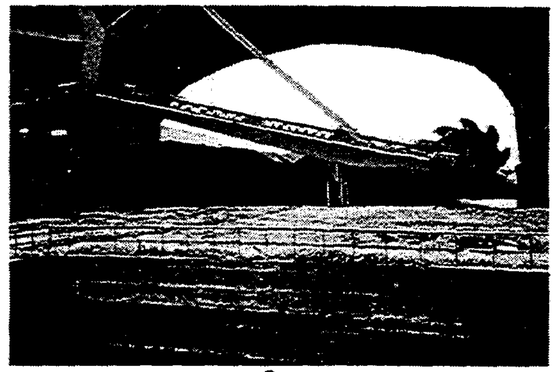

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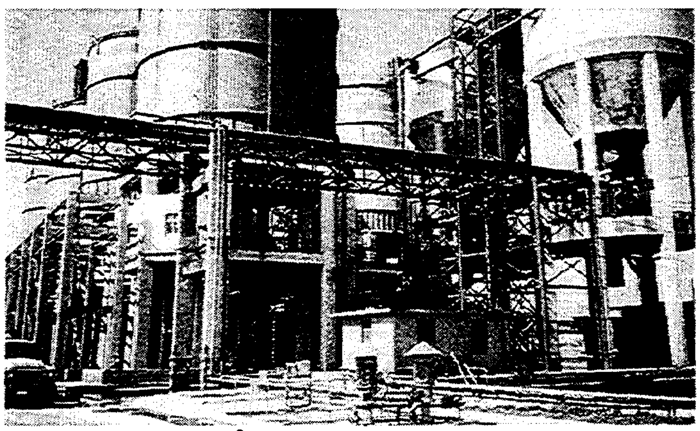

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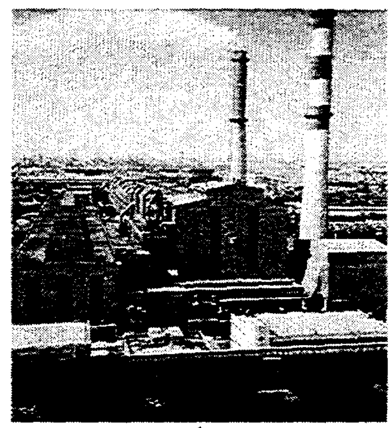

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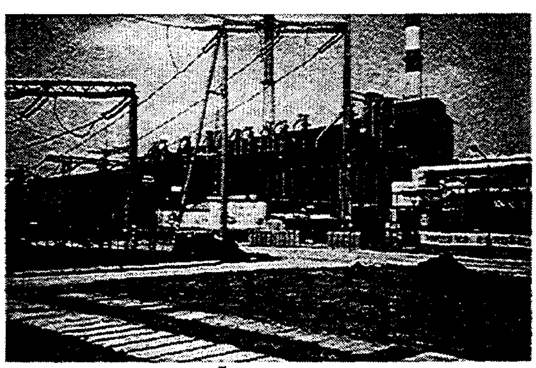

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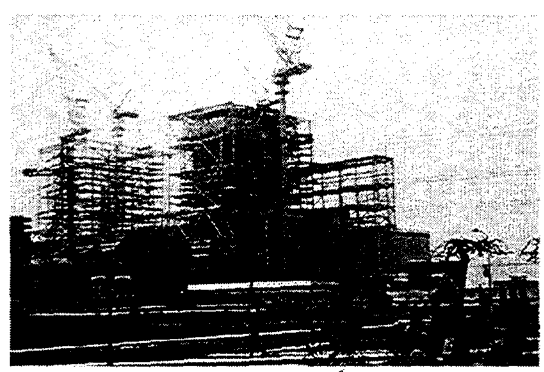

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1. Whole Plant; 2. Coal handling; 3. Ash handling; 4. Past: Previous Phases (I-V); 5. Present: Bank-financed (Phase VI);6. Future: Phase VII)

Yangzhou

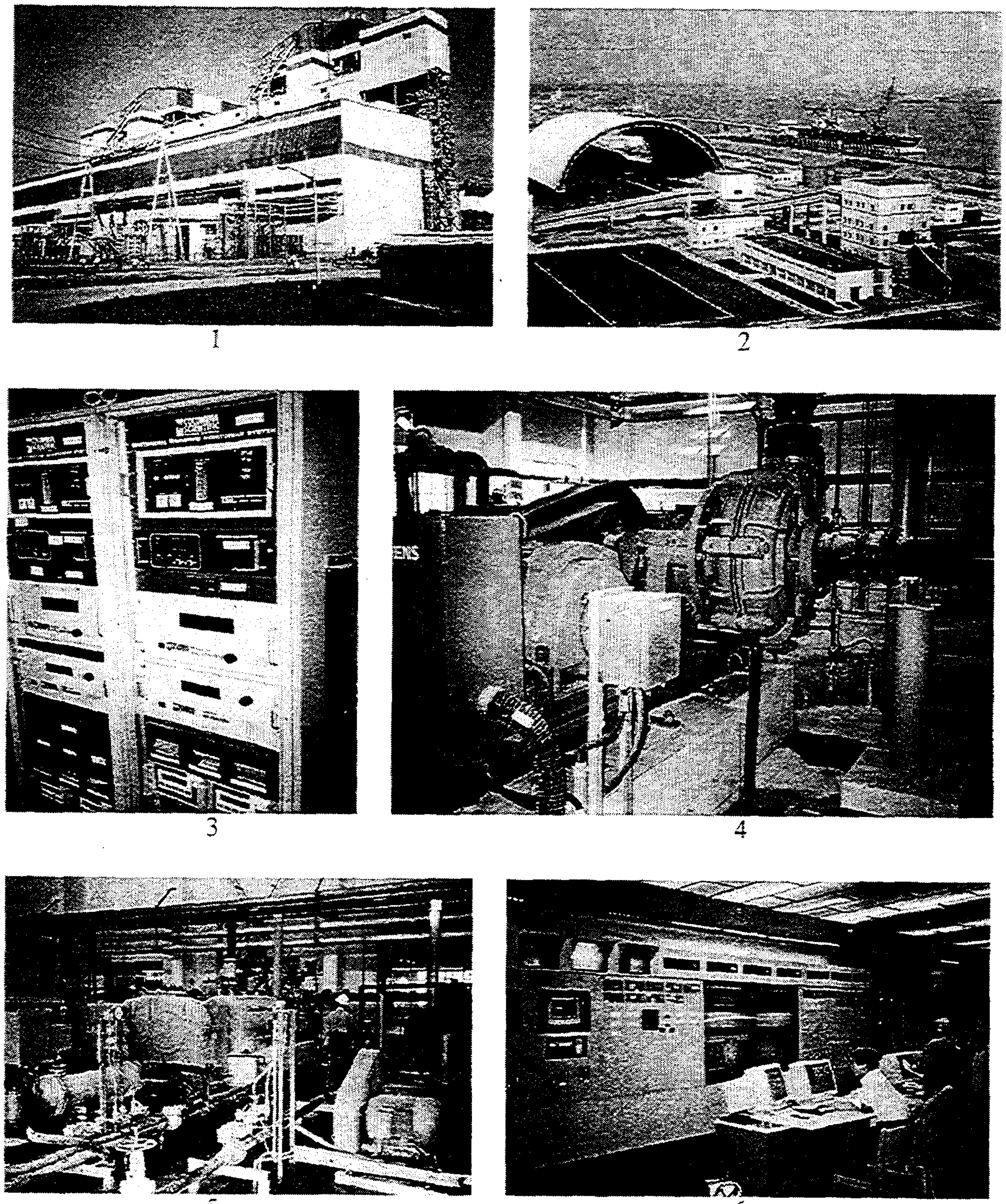
For the most part, mitigating measures as indicated in the SAR are similar to those implemented. The SAR identified use of bird repelling devices on the transmission line component. No one at the power station knew whether or not these were installed. Finally, ash yards were to be watered and trees planted to suppress fugitive dust generation, and again these actions had not been taken.

Generally speaking, the monitoring program does not meet the specifications presented in the EMP. Air quality monitoring is only done within plant boundaries by contract with NEPRI. No measurements are made beyond plant boundaries or at the ashyard as described in the EMP. Some of the simpler wastewater pollution parameters (pH, suspended solids, and COD) are monitored for chemical and human sewage effluents. However, measurements of heavy metals, BOD, and oil/grease are done by NEPRI. No monitoring of runoff is done at the slag and coal piles, thermal pollution at the cooling water discharge, and oily wastewater effluents. Noise measurements are made in a rather sophisticated manner both inside and outside the plant fence. However, no measurements of noise or electric fields are made along the transmission line.

A training program of 17 staff months was presented in the SAR, but the actual training was seven staff weeks, of which five staff weeks was international (France and Germany). Actual training was received by a supervisor and his subordinate. Upon return from overseas training, the supervisor changed positions and was no longer involved in environmental matters.

Four staff members are responsible for environmental management, including two chemists. They prepare monthly reports and submit them to the Jiangsu Provincial Electric Power Bureau, and the Jiangsu Environmental Protection Bureau. Any decisions/actions regarding remediation are made at the plant level.

Figure 3 Yangzhou Power Plant



1. Whole Plant; 2. Coal Handling; 3. CMU; 4.Ash Pump;
5. Ash Pump; 6. Central Control Room

YANSHI

With one very significant, and another minor, exception, the mitigation program as outlined in the SAR is faithful or superior to the mitigation program under implementation. The significant exception is the electrofilters used. According to the SAR, Units Three and Four were to be fitted with electrofilters with collection efficiencies equal to or better than 99.4 % to meet an exit dust concentration of 150 mg/Nm^3. Bid documents specified collection efficiencies of 99.2 %. The reason given was that technology for manufacturing higher efficiency electrofilters was unavailable in China during project implementation. Since electrofilters were originally to be procured under ICB, it is not clear how this variance was allowed. In fact the electrofilters that were installed are only providing collection efficiencies of 99.0 and 99.1%, respectively, which is inferior even to what is considered to be an overly generous design criteria.

The minor exception is related to sanitary wastewaters which were to receive secondary treatment. In practice, this effluent is slurried with ash and sent to the ash yard. Any excess water is discharged into the river. The claim is that mixing with ash and providing a long residence time would destroy any pathogens; however, pathogens are never measured in the ashyard effluent.

The monitoring program as practiced is reasonably faithful to the monitoring program as presented in the SAR. The primary difference is that the air quality monitoring which was to have been done with the mobile van (at the residential areas and the ashyard) has not been maintained because monitoring equipment in the van malfunctioned, and it has been very difficult to obtain spare parts.

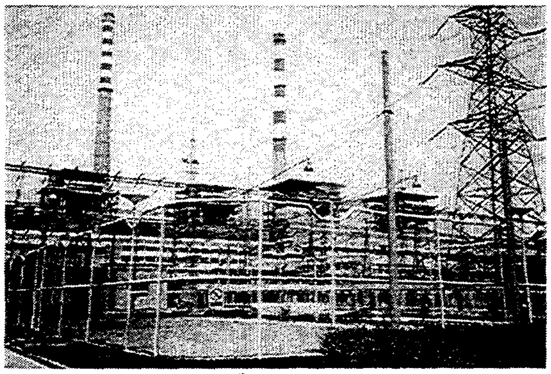
Another significant difference is the absence of monitoring for cooling tower blowdown and boiler cleaning water effluent. This is because these waters are slurried with the ash and recycled to the ashyard. Therefore, they are not discharged to any surface waters.

All locally purchased monitoring equipment identified in the SAR was secured with the exception of the polarograph, which was deemed unnecessary. The only internationally procured monitoring equipment was the continuous emission analyzers for flue gas sampling. All other parameters are analyzed with manually collected samples analyzed at the power station laboratory, which has sufficient analytic capability.

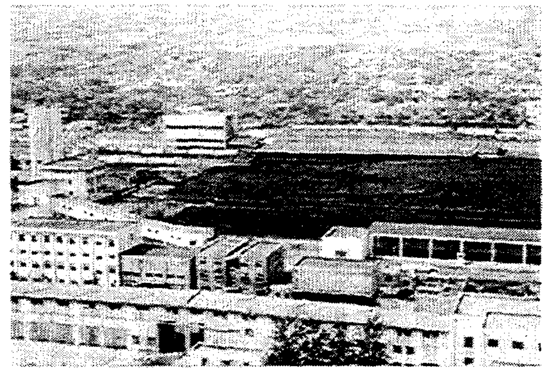
The SAR identified training, but no specific details were provided. Nonetheless a reasonable program of staff training both domestically (four staff/seven days on automatic monitoring systems) and internationally (one staff/three weeks in the USA on mobile van monitoring systems, and one staff/three weeks in Australia on ash handling systems) was implemented.

Environmental data is collected by the plant Environment Department which regularly sends the information to the Luoyang Municipality Environmental Protection Bureau, and to the Environment Department of the Henan Electric Power Corporation (HEPC) on a monthly, seasonal, and annual basis.

Picture 4 Yenta Power Plant



1



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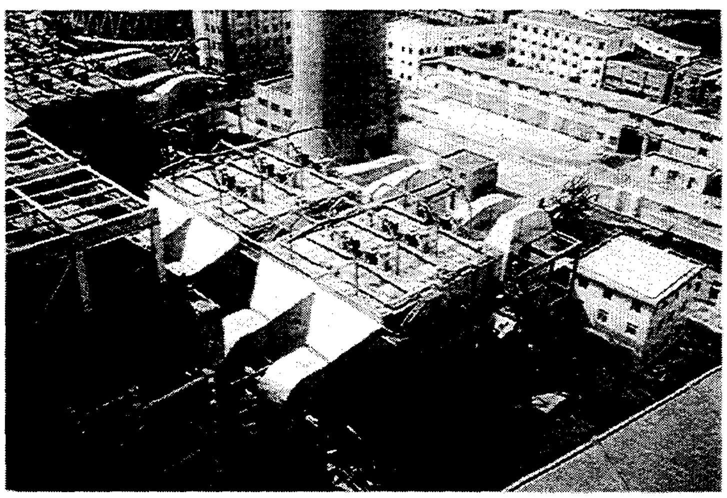

3

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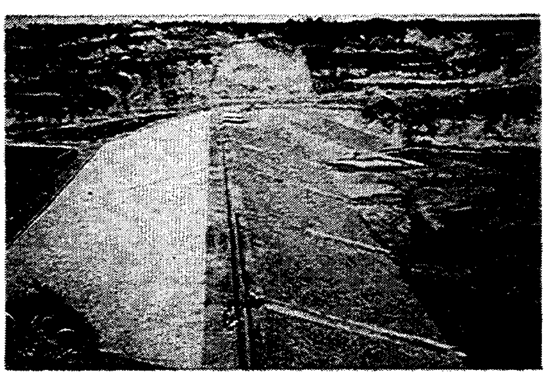
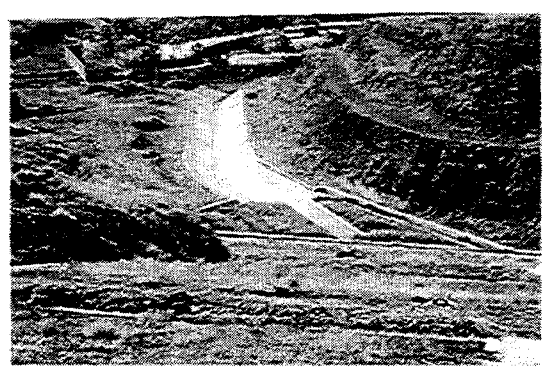


5



6

1.Whole plant; 2. Coal handling; 3. ESP;
4. Ash pond; 5.Ash pond dam; 6. Ash pond water discharge

Remediation requires HEPC approval. Remediation costs less than 500,000 RMB are done by plant staff directly. Greater expenditures are paid from an HEPC managed technical fund.

3.2 COMPLIANCE WITH UPDATED WORLD BANK ENVIRONMENTAL GUIDELINES (1998)

Most power projects under consideration were prepared prior to the time updated World Bank Environmental Guidelines for thermal power stations were in effect. Nonetheless it is of interest to explore how well these plants are currently operating in comparison to these guidelines, to see if the additional control (and cost) burden they would have imposed had they been in effect several years earlier.

Most of the new World Bank guidelines are met by most of the plants. The notable exception is for dust emissions. The only real problem is Yanshi whose dust emission levels exceed even the old environmental guidelines. Officials at Zouxian, Wai Gao Qiao, and Yanshi power stations agreed to send the World Bank estimates for the incremental costs to meet the new guidelines. As yet, this information has not been received except from Yanshi.

Also of substantial significance is the fact that none of the power stations require very expensive flue gas desulfurization systems. However, this more strongly reflects the policies of the Chinese government to encourage the use of very low sulfur coals rather than the World Bank guidelines per se.

Thus it can be reasonably concluded that adoption of the new World Bank thermal power guidelines would not have in the past and would likely not in the future impose a significant financial burden to Chinese power projects.

4
DIAGNOSIS AND RECOMMENDATIONS

4.1 ISSUES AND ANALYSIS

As a result of this review, several issues have been identified as requiring closer examination. Most are related to application and interpretation of environmental standards, and their impact on costs and the long term environmental management of the sector.

Sulfur Dioxide Emission Standards

There are two types of standards: mass-based (e.g. tons/day), and concentration-based (e.g. mg/Nm^3). Mass-based emissions can be used to calculate flue gas concentrations of sulfur dioxide using the heat rate (gce/kWh) and flue gas flow (350 Nm3/GJ with 6% excess O_2).

Based on the concentration of SO_2 on the flue gas, ambient air quality at ground level can be calculated using traditional Gaussian dispersion models. The added portion of SO_2 which touches ground under the most unfavorable conditions must be added to the already existing, ambient SO2 concentration to give us a complete picture of ground level condition. In the plants which the team examined, the maximum portion of additional pollution from the plant is of the order of up to five percent. This clearly shows that for urban air quality, the portion attributable to the power sector is minor compared to other local sources.

The Bank's new standard on mass-based SO_2 emissions could be interpreted as overly strict, compared to the concentration based standard, especially for some plants which plan to expand. For example, approximately 0.2t/MW/day equals 8.3g/kWh of SO2 (0.1t/MW/day equals to 4.16g/kWh). According to 1997 data from SPC, the average SO_2 emissions of thermal power plants in China is 84.6g/kWh, ten times of the Bank's requirement. The average SO2 mass based emissions of the Bank-financed power plants is 3.69g/kWh which is only 4 percent of the Chinese national average. This again reinforces the positive impact the Bank financed plants are having on the sector.

If coal sulfur content of less than 0.5 percent can be achieved through coal washing at a reasonable cost, the SO_2 emissions can meet both the new WB standard (0.1t/MW/day) and Chinese new standard ($1200mg/Nm^3$) without adopting flue gas desulfurization (FGD). Most of the plants in the survey use coals which range in sulfur content from 0.4 to 0.9 percent sulfur.

The effect of the heating value of the coal and the overall plant efficiency are clearly linked in that a cleaner coal with concomitant higher heating value will require less coal to produce the same energy leading to less emissions, lower wear and tear on all the plant systems, etc. Low quality (low heat value and relative high sulfur content) coal, often found at mine-mouth power plants like Yanshi, will have difficulty meeting new WB standards for emissions.

PARTICULATE EMISSIONS

Beilungang I and II, Wujing, and Yangzhou currently meet the Bank's new standard although they are not required to. However, Yanshi and Zouxian will need to improve the quality of coal or the efficiency of the ESP in order to meet the Bank's new standard. In most cases, the Chinese standards on particulate emissions are much less strict than the Bank's requirement.

Again, improving the quality of coal by reducing ash content and increasing heat value should be considered as an option for meeting the Bank's new standard when also considering improving ESP efficiency. According to data provided by Yanshi, to meet the Bank's new standard on PM emissions, the cost of renovating the ESP is estimated to be $2.2 million, equal to $0.26 million per year of a 20-year loan at 10% interest rate. ($0.14/ton). This appears much more favorable than coal washing at $15-30 /ton[1].

The Bank standard for particulate emissions was changed from 150mg/Nm^3 to 50mg/Nm^3. The impact of this change on $PM_{2.5}$ or PM_{10}, the most dangerous particulate to human health, is still unclear. Although the particulate emissions are reduced to 50mg/Nm^3 by improving the efficiency of ESP, emissions of fine particulates may not decrease proportionally. The additional cost of adopting the new Bank standard may not provide the fine particulate reduction expected. There is no separate requirement on fine particulate emissions in either Bank or China standards.

DISPERSION AND THERMAL POLLUTION MODELING

The incremental contribution of the power station to ambient air quality is normally determined by standard mathematical models (usually some variant of a Gaussian dispersion model). Together with estimates of background air quality, an overall estimate of air quality with the proposed power plant in operation can be made. These estimates are then compared to air quality standards to determine whether or not these standards would be violated with project implementation.

Generally, the Bank requires one year of background data. Significant sums may be spent in acquiring the data. However, between the time background data are collected and the power plant is operating, ambient conditions may have changed appreciably, making the whole impact analysis difficult, if not impossible, to verify. Clearly, this was a problem at all plants visited. Fortunately, the modeling efforts indicated that the power plant contributions to overall ambient pollution was never more than five percent of ambient air standard.

Thermal pollution impacts are also the subject of extensive modeling (either physical or mathematical, and sometimes both, e.g. Wai Gao Qiao). This modeling, normally done when cooling systems are considered, can also be quite complex and expensive to perform and verify.

Both air quality and (in some instances) thermal pollution predictions form an integral part of the

[1] Advanced physical separation, page 9, A Planner's Guide for Selecting Clean Coal Technologies for Power Plants, World Bank Technical Report No. 387. Conventional coal cleaning costs range between $2~10.

environmental assessment report for thermal power stations. EA predictions should be verified after plant operations begin, to confirm the modeling work and to check impacts. The following table summarizes verification activities for each station visited.

Table 4-1 Verification of Environmental Data

POWER STATION	VERIFICATION			
	Air Quality		Thermal Pollution	
	Done	**Agreement (EA vs. Actual)**	**Done**	**Agreement (EA vs. Actual)**
Zouxian	Requested	TBD	NA	NA
Wai Gao Qiao	NA*	NA*	NA*	NA*
Beilungang I	Yes	Very poor	NA	NA
Beilungang II	NA**	NA**	NA**	NA**
Wujing	No	-	Yes	Very Good
Yangzhou	No	-	No	-
Yanshi	No	-	No	-

Notes: * Plant not yet operational, however both physical and mathematical modeling of the thermal pollution was performed
** Plant not yet operational

These results reflect a lack of commitment to confirming air and water quality predictions as outlined in the EA.

For air quality, acquisition of background data and modeling is both time-consuming and expensive. Since results are never verified, and verification would take even more time and money, does the exercise add value? It is recommended that the Bank review this requirement, and attempt to develop alternative analytical procedures that may be less accurate, but can be performed in less time and at less expense to the Borrower.

Ash Management

Ash management at all operating plants visited was implemented in a relatively sound and environmentally safe manner. Large ash ponds were created (each side measuring several hundred meters) requiring on-site storage silos at each plant, as well as long sluice pipes (several km) to the disposal sites. These facilities added significantly to the cost of operations. Disposal sites tended to be near water bodies or areas where farming was marginal. Significant civil works are required at these ashyards to assure that the ash remains contained and drainage is controlled.

Water Pollution Control

To meet Chinese and World Bank requirements, power plant municipal waste water needs secondary treatment before discharge. At several plants, wastewater treatment systems are not operated because the wastewater volume is too small. Under these situations, wastewater is mixed with industrial wastewater, then treated.

Environmental Aspects of Construction Activities and Emergency Situations

Environment management plans often ignore construction and emergency situations. The construction phase of a greenfield thermal power station can take several years. During this period, the potential for significant and permanent environmental impacts is substantial. However, Bank guidelines and EA requirements on these aspects are limited. China has adopted strict environmental requirements concerning construction activities, which is also a major component of its EA procedure.

For Wai Gao Qiao, the most recent Bank-financed project, the EA approved by both Government of China and the World Bank had virtually no discussion of construction phase impacts or their mitigation.

Role of Local Environmental Protection Bureaus

At all plants visited, arrangements were made to meet with Provincial Environmental Protection Bureaus (EPBs). In all cases, the Provincial EPBs confirmed that all plants met or exceeded Chinese standards, the EAs had been approved, and are at the appropriate stage of the "Three Synchronizations" process[2]. However, there seemed to be severe shortcomings with respect to involvement of local EPBs in the project development phases, and even less attention paid to public participation.

Since these power stations represent major investments, the key environmental institutions involved with EA review and approval are SEPA at the national level, and the Provincial EPBs. Local EPBs do not appear to be integrated into this process in any real sense and there does not seem to be any attempt made by the higher institutions to engage them. For example, in the few instances where the subject was pursued, there was no cognizance of the fact that the EAs had to be placed in a public place for comment. With the local authorities uninvolved, it is not surprising that affected groups are even further removed from the process, since it is to these local authorities that such groups would first express any concerns.

Under the latest revision to the World Banks' policy on environmental assessment (OP/BP/GP 4.01), public involvement in the EA process and public notification has become more clearly focused as well as more stringent than in the past. For thermal power stations that are invariably identified as "Category A" projects, this should be interpreted as a situation where Bank requirements are more stringent and defined than those of the Chinese authorities.

Monitoring, Reporting and Disclosure

Monitoring equipment: Ambient air quality monitoring needs the involvement of local EPBs. Continuous monitoring equipment (CME) systems in these plants are imported from different manufactures and countries. The results are usually not comparable. Further

[2]The "Three Synchronizations" process are an integral part of the overall Chinese EIA process. The first synchronization assures that the EA contains appropriate mitigation measures, the second synchronization assures that the mitigation measures are *in fact* installed in the project, and the third synchronization assures that the mitigating measures are *operating* in accordance with prescribed performance criteria.

work needs to be done to determine how serious a problem this is. The assumption is that if the data is never formally reviewed, it never falls under serious scrutiny.

Training program: The training programs attached to these projects were generally completed. However, several problems were identified; such as (a) the staff participating the training, especially overseas, are often high-level officials; and (b) the lower-level staff who were trained are very likely to be promoted to managerial level rather than doing the real monitoring work.

Public participation: No public notice for the EA disclosure was found during the mission. The EA reports for some projects were not available in the Bank Infoshop, or in other Bank libraries. Public consultation was only being introduced in some recent projects.

Reporting: Information data sheets varied widely in terms of formats, units, and items. No environmental monitoring data was shown in plant operation reports. The monitoring on-line data usually goes to a central monitoring station rather than the central control room. It is hard to analyze the relationship between the operational performance and environmental performance of the plants. Reports often go to provincial power bureaus. Local EPBs were often ignored.

Project Audit of Plant Environmental Performance: In China, SPC and SEPA require power plants to carry out a two-week campaign to review the environmental performance within one year of operation. The evaluation report, based on the findings of the campaign, is a requirement of the project completion clearance report. So far, Beilun I, Wujing, Yanshi, Zouxian have finished the campaign. The mission found the monitoring items and the standards applied are on a project by project basis, and some were not consistent with EA reports. The campaigns focus more on on-site monitoring during the campaign period than the overall review based on the operational history of the plant. The format of the report also varies from project to project. In the Bank, the post review on a project's environmental performance is part of the project implementation completion (PIC) and project evaluation report. Comprehensive environmental monitoring and management plans were included in SAR stating resources.

4.2 RECOMMENDATIONS

EXAMINE COAL QUALITY

Using high quality coal with a high heat value, low ash and sulfur content is critical for the plant to meet the Bank's new standard, as well as future stricter Chinese standards. Coal beneficiation and washing can reduce ash and sulfur content, and increase the heat value as well. Using a higher heat value coal, the plant requires less fuel to achieve the same amount of electricity output, resulting in less particulate and SO_2 emissions. The electricity consumption for coal handling, ash handling, ESP and fans will be reduced, thus increasing overall plant efficiency. Therefore high quality coal enhances the overall environmental performance of the plant.

Further analysis is required of the environmental and financial tradeoffs of improved coal quality. Specifically, the notion of using washed coal, resulting in improved heat rates producing less pollutants, needs to be looked at carefully in light of tradeoffs, such as pollution created in the washing process. The team feels that this is where significant progress can be achieved in both the power sector and for other users of coal as well. Costs associated with flue gas treatment versus coal beneficiation and cleaning (reducing ash as well) are not well understood. Additional work along these lines is recommended.

ENHANCE THE ROLE OF LOCAL EPBS

The role of local EPBs in the communities near these plants is unclear. The team found that in most cases, the provision of due diligence during construction and operations has been minimal. Local EPBs often deferred to power plant environmental staffs for sampling and self-reporting. In spite of generally good performance by the sector, there still exists the notion that environment is not a top priority, but an issue that is addressed only when a crisis occurs. This view needs to be modified. The team recommends a new partnership between the EPB and environmental staff of the local power plant. However, this relationship must be based on the fact that it is the EPBs responsibility to monitor the environmental performance, report results to the local government body and assess damages for non-compliance.

INCREASE ENVIRONMENTAL SUPERVISION AND TA

Since the Bank has been somewhat lax in its environmental supervision of these plants, the team recommends that more effort should be expended in future to supervise these projects. The Bank should continue to be engaged with China in the improvement of the power sector. For example, as natural gas reaches many urban areas, there will be potential for even cleaner energy either by firing gas in existing facilities or building combined cycle plants. Some of these will be IPPs. The involvement of the Bank is key to the development of the sector and assisting the government in implementing private power.

ENHANCE SPC ENVIRONMENTAL CAPABILITY

Enhancing SPC environmental capability should be a priority. Currently, the unit consists of five people who spend most of their time in Beijing. The team recommends that they develop a national environmental data base with SEPA on the power sector. In addition, the unit needs to develop an extension capacity to assist the environmental staffs of the various power plants that it oversees.

IMPROVE ASH DISPOSAL

Ash disposal is relatively well managed (depending on the plant) at the plants the team visited. Since the coals used are fairly high in ash content (10 to 40 percent), there are very large quantities of ash to be disposed of. In most cases the ash is slurried to large ponds located along rivers or hilly areas where the ash is used as fill. In both cases, these fills generate a great deal of leachate which usually drains away naturally. However, if the ash could be recycled into construction materials, this would avoid significant disposal costs. To some extent this is already being done at a number of locations, but should be increased if possible.

Rationalize Water Pollution Requirements

Cooling water taken in by these plants is often of low quality requiring treatment before it can be used in cooling systems. Yet the requirement is that it be discharged at a higher standard. It is monitored and if it does not meet the effluent standards, the plant can be fined, which makes little sense. A more rational approach needs to be developed whereby these plants are not forced to treat their effluents to a higher standard than the available supply.

Optimizing Pollution Control

Additional work needs to be done to optimize pollution control for both emissions and effluents. Management of pollutants is driven by Chinese national standards and by Bank standards regardless of the local pollution situation. The notion of tradable emissions is only now beginning to be considered. There is no real market for this approach, although there has been some rudimentary experience in Shanghai — but this needs to be refined and extended to other parts of China.

Enhanced Public Participation

The EA and monitoring reports should be accessible by affected groups, who should be informed through public notice. Local EPBs should be involved in environmental monitoring and management.

EA During Construction

An effort should be made to include environmental guidance during the construction phase of these projects. The Bank's environmental document does not address this issue.

Air Quality Impacts Assessment

A considerable amount of time and resources in EA preparation is devoted to collecting and analyzing air quality baseline data, and predicting air quality impacts. No one verifies these predictions; indeed it is near impossible, or at least extremely expensive, to do so. It is recommended that the Bank undertake a serious review of this requirement with the objective of developing alternative information requirements that can be secured in a shorter time and at less expense, and provide nearly the same level of information regarding project related air quality impacts.

Appendix A Overall Power Sector Performance

No.	Indicator	Unit	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	GDP	billion Yuan	45178	48624	52947	59345	71710	89644	102022	119625	149283	169092	185479	216178	266381	346344	467594	584781	678846	747724
2	Total installed Capacity	MW	65870	69130	72360	76440	80120	87050	93820	102900	115500	126640	137890	151473	166533	182911	199897	217124	236542	254238
3	Hydro	MW	20320	21930	22960	24160	25600	26410	27540	30190	32700	34580	36046	37883	40681	44593	49061	52184	55578	59730
4	Thermal	MW	45550	47200	49400	52280	54520	60640	66280	72710	82800	92060	101844	113590	125852	138318	148736	162940	178864	192408
5	Nuclear	MW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2100	2100	2100	2100
6	Total Generation	TWh	300.6	309.3	327.7	351.4	377.0	410.7	449.5	497.3	545.2	584.7	621.3	677.5	754.2	836.4	927.9	1006.9	1079.4	1134.2
7	Hydro	TWh	58.2	65.5	74.4	86.4	86.8	92.4	94.5	100.0	109.1	118.5	126.3	124.8	131.6	150.7	166.8	186.8	186.9	194.6
8	Thermal	TWh	242.4	243.8	253.3	265.0	290.2	318.3	355.0	397.3	436.1	466.2	495.0	552.6	622.7	685.7	747.0	807.3	878.1	925.2
9	Nuclear	TWh	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	14.0	12.8	14.3	14.4
10	Heat rate (supply)	gce/kWh	448	442	438	434	432	431	431	432	431	432	427	424	420	417	414	412	410	408
12	Heat rate (generation)	gce/kWh	413	407	404	400	398	398	398	397	397	397	392	390	386	384	381	379	377	375
12	Plant consumption	%	6.44	6.4	6.32	6.21	6.28	6.42	6.54	6.67	6.96	6.81	6.9	6.94	7	6.96	6.9	6.78	6.88	6.8
13	Hydro	%	0.19	0.2	0.21	0.23	0.25	0.28	0.28	0.31	0.34	0.3	0.3	0.32	0.37	0.41	0.42	0.37	0.51	0.51
14	Thermal	%	7.65	7.76	7.77	7.78	7.7	7.78	7.83	7.87	7.94	8.12	8.22	8.13	8.08	8.08	7.99	7.95	7.94	7.81
15	Line loss	%	8.93	8.98	8.64	8.53	8.28	8.18	8.15	8.48	8.18	8.18	8.06	8.15	8.29	8.52	8.73	8.77	8.53	8.2
16	Operation hours	Hours	5078	4955	5007	5101	5190	5308	5388	5430	5313	5171	5036	5030	5029	5068	5233	5216	5033	4765
17	Hydro	Hours	3293	3520	3708	4104	3860	3853	3882	3795	3710	3691	3800	3675	3567	3730	3877	3867	3570	3387
18	Thermal	Hours	5775	5511	5542	5513	5748	5893	5974	6048	5907	5716	5413	5451	5462	5455	5574	5459	5418	5114
19	PM Emissions	g/kWh											84.8	79	76.1	68.7	61.8	54.9		42.3
20	SO Emissions	g/kWh											97.7	99.8	96.5	95.2	90.6	87.6		84.6
21	NOx Emissions	g/kWh											53.5	52.9	52	51.3	46.4	44.5		42.3

Appendix B Performance Summary of Bank-Financed Power Plants in China

No.		Description	Beilun I	Wujing	Yanshi	Beilun II	Zouxian	Yangzhou
1	Basic Information	Unit Capacity, MW	600	300	300	600	600	600
		Unit number	2	2	2	3	2	2
		Stack Height, m	240	210	240	240	240	240
		Ash Content, %	14.7%	7.9%	30.6%	15.5%	22.4%	10.9%
		Sulfur Content, %	0.85%	0.62%	0.81%	0.63%	0.70%	0.36%
		Heat Value, kJ/kg	22966	22474	17201	22404.8	22535	21610
		ESP Efficiency, %	99.80%	99.80%	99.20%	99.90%	99.60%	99.80%
		Heat rate, gce/kWh	307	332	350	300	320	337
		Plant Efficiency, %	40.1%	37.1%	35.2%	41.0%	38.4%	36.5%
		Flue gas volume, Nm3/kg(coal)	8.0381	7.8659	6.02035	7.84168	7.88725	7.5635
		Coal consumption, tpd	11265	6224	8573	16925	11966	13141
2	Particulate	PM Emissions, tpd	3.3	1.0	21.0	2.6	10.7	2.9
		PM Emissions (calculated), mg/Nm3	36.6	20.1	406.5	19.7	113.6	28.8
		PM Emissions (reported), mg/Nm3	30.0	7.0	210.0	34.1	80.0	24.0
		Chinese Standard, mg/Nm3	300	150	400	200	300	200
		World Bank Standard (Old) for PM, mg/Nm3	100	100	100	100	100	100
		World Bank Standard (New) for PM, mg/Nm3	50	50	50	50	50	50
3	Sulfur Dioxide	SO2 Emissions (calculated), mg/Nm3	1692	1261	2153	1285	1420	762
		SO2 Emissions (reported), mg/Nm3	1392.1	619	849	889.6	956	383.2
		Chinese Standard for SO2, mg/Nm3	2100	2100	2100	2100	2100	2100
		World Bank Standard for SO2, mg/Nm3	2000	2000	2000	2000	2000	2000
		SO2 Emissions (calculated), tph	6.38	2.57	4.63	7.11	5.58	3.15
		SO2 Emissions (reported), tph	6.50	1.28	2.34	8.50	4.74	2.44
		SO2 Emissions (calculated), tpd	153	62	111	171	134	76
		SO2 Emissions (reported), tpd	156	31	56	204	114	59
		Chinese Standard for SO2, tpd	147	400	421	220	249	517
		World Bank Old Standard for SO2, tpd	200	110	480	300	403	500
		World Bank New Standard for SO2, tpd	170	75	70	180	120	170
4	NO_x	NO_x Emissions (reported), ppm	237	225	257	253	200	212
		Chinese Standard	317	317	317	317	317	317
		World Bank Old Standard, ppm	417	417	417	417	417	417
		World Bank Old Standard, ppm	365	365	365	365	365	365
5	Summary	PM (calculated), g/kWh	0.115	0.068	1.457	0.061	0.372	0.099
		PM (reported), g/kWh	0.094	0.024	0.753	0.105	0.262	0.083
		Bank-Financed Average, g/kWh	0.22	0.22	0.22	0.22	0.22	0.22
		Chinese Average, g/kWh	42.30	42.30	42.30	42.30	42.30	42.30
		SO2 (calculated), g/kWh	5.32	4.29	7.72	3.95	4.65	2.63
		SO2 (reported), g/kWh	5.42	2.13	3.90	4.72	3.95	2.03
		Bank-Financed Average, g/kWh	3.69	3.69	3.69	3.69	3.69	3.69
		Chinese Average, g/kWh	84.60	84.60	84.60	84.60	84.60	84.60
		NOx, g/kWh	1.53	1.57	1.89	1.60	1.35	1.50
		Bank-Financed Average, g/kWh	1.57	1.57	1.57	1.57	1.57	1.57
		Chinese Average, g/kWh	42.3	42.3	42.3	42.3	42.3	42.3

Appendix C Provincial Power Sector Survey Form Sample

Part A: Institutional Framework of Environment Protection Administration in XXX Province

Part B: Performance of Coal-fired Power Plants

No.	Indicator	Unit	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1	GDP	billion Yuan																		
2	Total installed Capacity	MW																		
3	Hydro	MW																		
4	Thermal	MW																		
5	Nuclear	MW																		
6	Total Generation	TWh																		
7	Hydro	TWh																		
8	Thermal	TWh																		
9	Nuclear	TWh																		
10	Heat rate (supply)	gce/kWh																		
12	Heat rate (generation)	gce/kWh																		
12	Plant consumption	%																		
13	Hydro	%																		
14	Thermal	%																		
15	Line loss	%																		
16	Operation hours	Hours																		
17	Hydro	Hours																		
18	Thermal	Hours																		
19	PM Emissions	g/kWh																		
20	SO Emissions	g/kWh																		
21	NOx Emissions	g/kWh																		

Appendix D Power Plant Survey Form

Part A: Policy Framework

A1: Environment Protection Regulation and Policy

Item	Document	Date	Check
1	PRC Environmental Protection Law	12/26/89	
2	PRC Ambient Air Pollution Prevention and Mitigation Law	8/30/95	
3	PRC Solid Waste Environmental Pollution Prevention and Mitigation Law	10/30/95	
4	PRC Water Pollution Prevention and Mitigation Law	5/15/96	
5	PRC Environmental Noise Prevention and Mitigation Law	10/29/96	
6	Construction Project Environmental Protection Administration Regulation	1986	
7	Construction Project Environmental Protection Design Stipulation	1987	
8	Construction Project Environmental Protection Administration Procedure	1990	
9	Electric Power Industry Environmental Protection Administration Regulation	1996	
A2: Monitoring Reports			
1	Environment Assessment Report to SPC		
2	Project Completion Report: Environment		
3	EMD Report to Provincial EPB		
4	Monthly Operation Report (including major pollution mitigation and monitoring equipment, like ESP, SOX and NOX monitor)		
5	EMD Environment Monitoring Report		
6	Coal and Ash Analysis Reports		

Appendix D Power Plant Survey Form

Part B: Environmental Mitigating Measures

B1:Air quality

Item	Target	Measures	Compliance	Comments
1	SO2	Low sulfur coal (<0.95%); Stack height (240m)		
2	Dust	High efficiency ESP (>99.4%)		
3	Nox	Low Nox burner in Phase II		

B2:Waste water

Item	Target	Measures	Compliance	Comments
1	Circulating Cooling Water Blowdown	No chrome chemical are to be used. Blowdown is to be sent ash pond after neutralization		
2	Chemical Waste Water and Boiler Blowdown	Neutralization by acid or alkaline prior to discharge		
3	Boiler Cleaning Waste Water	Discharge after treatment in ash water quick reaction clarifier, resultant sludge disposal in ash yard (mineral acid), or inject waste water into boiler furnace for incineration (organic acid)		
4	Oil Contaminated Waste Water	Use flat flow oil scraping pond and air flotation pond in two stages		
5	Sanitary wastes	Secondary treatment system currently available. Expand if necessary		
6	Coal Yard Runoff	Collect and settle. Sludge sent to ash disposal site, effluent discharged		
7	Ash Yard Runoff	Settle and adding H2SO4 (acidification0 and sent to the Yellow River		

B3:Solid waste

Item	Target	Measures	Compliance	Comments
1	Fly Ash	Sluice to the Xi-Jia-Guo Ash Yard. Surface to be maintained wet. Rainwater from surrounding areas directed to drainage systems. Sides planted with trees to contain dust. After useful life, ash yard is to be revegetated		
2	Bottom Ash	Ground and trucked to the Xi-Jia-Guo Ash Yard		

B4:Noise

Item	Target	Measures	Compliance	Comments
1	Noise	Noise isolating covers, walls, or closets shall be provided where necessary. Silencers shall be provided for boiler safety valves, piping, blowout, and forced draft fans.		

Appendix D Power Plant Survey Form

Part C: Monitoring Plan

C1: Monitoring Plan Checklist (Power Plant)

Item	Description	Location	Specification	Frequency	Responsibility	Comments
1	Environmental Management Department (EMD)					
2	Plant greening					
3	Plant tidiness and cleanness					
4	Coal sampling analysis					
5	Fugitive dust					
6	Fugitive dust					
7	Stack height					
8	Stack TSP					
9	Stack SO2					
10	Stack Nox					
11	Ambient TSP					
12	Ambient SO2					
13	Ambient Nox					
14	Plant area drainage					
15	Chemical plant neutralizing pond drainage					
16	Domestic sewage					
17	Coal yard drainage					
18	Underground water					
19	Cooling water structures					
20	Cooling water temperature					
21	Construction noise					
22	Noise inside the plant					
23	Noise outside the plant					
24	Bunding					
25	Emergency equipment					
26	Rail transportation system					
27	Coal yard system					
28	Ash yard system					

Appendix D Power Plant Survey Form

C2: List of Instruments and Equipment to Be Purchased

Item	Instrument/device type	Code	Number	Compliance	Remarks	
	Locally					
1	1/1000 precision analytical balance					
2	Type 251 spectroscopic meter					
3	pH meter					
4	Polarograph					
5	Precision integrated sound level meter					
6	Dust measuring instrument					
7	Velocity meter					
8	Wind direction and speed meter					
9	Suspended particle sampler					
10	Air sampler					
11	Electronic calculator					
12	Conductivity meter					
	Needs foreign exchanges					
13	Continuous automatic flue gas analyzer (SO2, Nox)					
14	Flue gas automatic monitor for TSP					
15	pH continuous automatic monitor					
16	COD measurement equipment					
17	BOD1 measurement equipment					
18	Oil measuring meter					
19	Dust measurement apparatus for work area in the main power house					

Appendix D Power Plant Survey Form

Part C: Data Summary

C1: Fuel Characteristics

Coal Type	Unit	Design	Check	Actual_1	Actual_2		Comments
Mad	%						
Mt	%						
Aar	%						
Vdaf	%						
Qnet,ar	J/g						
Car	%						
Har	%						
St,ar	%						
Nar	%						
Oar	%						
HGI							

C2: Ash Characteristics

Ash analysis	Unit	Design	Check	Actual_1	Actual_2		Comments
DT	C						
ST	C						
FT	C						
SiO2	%						
Al2O3	%						
Fe2O3	%						
CaO	%						
MgO	%						
SO3	%						
K2O	%						
Na2O	%						
TiO2	%						

C3: Air Emissions

Pollutants	Unit	Standard	Background	Point 1	Point 2	Point 3	Comments
PM	mg/Nm3						
	ton/day						
	ton/year						
PM10	mg/Nm3						
	ton/day						
	ton/year						
SO2	mg/Nm3						
	ton/day						
	ton/year						
Nox	mg/Nm3						
	ton/day						
	ton/year						

C4: Liquid Effluents

Parameter		Standard	Background	Point 1	Point 2	Point 3	Comments
Temperature	C						
pH	mg/L						
Fluoride	mg/L						
Suspended Solids (SS)	mg/L						
Oil/grease	mg/L						
Assen	mg/L						
Cr6+	mg/L						
Hg	mg/L						
Cd	mg/L						
Pb	mg/L						
BOD5	mg/L						
CODcr	mg/L						
CODmn	mg/L						
Phenol	mg/L						
Sulfide	mg/L						
Total amount	ton/year						

C5: Solid Waste

Waste production	Unit	daily	yearly				Comments
Ash discharge	ton						
FGD	ton						

C6: Ambient Noise

Monitoring (or sensitive) Points	Unit	Maximum Allowable Leq (hourly)	Actual				Comments
1	dB(A)						
2	dB(A)						
3	dB(A)						

C7: Operating Parameters

Parameters	Unit	Design	Maximum	Minimum	Average		Comments
Flue gas temperature	C						
Excess air coefficient							
Flue gas flow rate	m/s						
Power supply to ESP	kWh						
Combustion temperature	C						
Boiler efficiency							
ESP efficiency							
Plant efficiency							
Coal consumption	ton/year						
Water consumption	ton/year						
Power consumption	kWh/year						
Power generation	kWh/year						

Appendix E
World Bank: Thermal Power Guidelines for New Power Plants

Industry Description and Practices

This document sets forth procedures for establishing maximum emissions levels for all fossil-fuel-based thermal power plants with a capacity of 50 or more megawatts of electricity (MWe) that use coal, fuel oil, or natural gas.[1]

Conventional steam-producing thermal power plants generate electricity through a series of energy conversion stages: fuel is burned in boilers to convert water to high-pressure steam, which is then used to drive a turbine to generate electricity.

Combined-cycle units burn fuel in a combustion chamber, and the exhaust gases are used to drive a turbine. Waste heat boilers recover energy from the turbine exhaust gases for the production of steam, which is then used to drive another turbine. Generally, the total efficiency of a combined-cycle system in terms of the amount of electricity generated per unit of fuel is greater than for conventional thermal power systems, but the combined-cycle system may require fuels such as natural gas.

Advanced coal utilization technologies (e.g., fluidized-bed combustion and integrated gasification combined cycle) are becoming available, and other systems such as cogeneration offer improvements in thermal efficiency, environmental performance, or both, relative to conventional power plants. The economic and environmental costs and benefits of such advanced technologies need to be examined case by case, taking into account alternative fuel choices, demonstrated commercial viability, and plant location. The criteria spelled out in this document apply regardless of the particular technology chosen.

Engine-driven power plants are usually considered for power generation capacities of up to 150 MWe. They have the added advantages of shorter building period, higher overall efficiency (low fuel consumption per unit of output), optimal matching of different load demands, and moderate investment costs, compared with conventional thermal power plants. Further information on engine-driven plants is given in Annex A.

Waste Characteristics

The wastes generated by thermal power plants are typical of those from combustion processes. The exhaust gases from burning coal and oil contain primarily particulates (including heavy metals, if they are present in significant concentrations in the fuel), sulfur and nitrogen oxides (SO_x and NO_x), and volatile organic compounds (VOCs). For example, a 500 MWe plant using coal with 2.5% sulfur (S), 16% ash, and 30,000 kilojoules per kilogram (kJ/kg) heat content will emit each day 200 metric tons of sulfur dioxide (SO_2), 70 tons of nitrogen dioxide (NO_2), and 500 tons of fly ash if no controls are present. In addition, the plant will generate about 500 tons of solid waste and about 17 gigawatt-hours (GWh) of thermal discharge.

This document focuses primarily on emissions of particulates less than 10 microns (μm) in size (PM_{10}, including sulfates), of sulfur dioxide, and of nitrogen oxides. Nitrogen oxides are of concern because of their direct effects and because they are precursors for the formation of ground-level ozone. Information concerning the health and other damage caused by these and other pollutants, as well as on alternative methods of emissions control, is provided in the relevant pollutant and pollutant control documents.

The concentrations of these pollutants in the exhaust gases are a function of firing configuration, operating practices, and fuel composition. Gas-fired plants generally produce negligible quantities of particulates and sulfur oxides, and levels of nitrogen oxides are about 60% of those from plants using coal. Gas-fired plants also release lower quantities of carbon dioxide, a greenhouse gas.

Ash residues and the dust removed from exhaust gases may contain significant levels of heavy metals and some organic compounds, in addition to inert materials. Fly ash removed from exhaust gases makes up 60–85% of the coal ash residue in pulverized-coal boilers. Bottom ash includes slag and particles that are coarser and heavier than fly ash. The volume of solid wastes may be substantially higher if environmental measures such as flue gas desulfurization (FGD) are adopted and the residues are not reused in other industries.

Steam turbines and other equipment may require large quantities of water for cooling, including steam condensation. Water is also required for auxiliary station equipment, ash handling, and FGD systems. The characteristics of the wastewaters generated depend on the ways in which the water has been used. Contamination arises from demineralizers, lubricating and auxiliary fuel oils, and chlorine, biocides, and other chemicals used to manage the quality of water in cooling systems. Once-through cooling systems increase the temperature of the receiving water.

Policy Framework

The development of a set of environmental requirements for a new thermal power plant involves decisions of two distinct kinds. First, there are the specific requirements of the power plant itself. These are the responsibility of the project developer in collaboration with relevant local or other environmental authorities. This document focuses on the issues that should be addressed in arriving at project-specific emissions standards and other requirements.

Second, there are requirements that relate to the operation of the power system as a whole. These strategic issues must be the concern of national or regional authorities with the responsibility for setting the overall policy framework for the development of the power sector. Examples of such requirements include measures to promote energy conservation via better demand-side management, to encourage the use of renewable sources of energy rather than fossil fuels, and to meet overall targets for the reduction of emissions of sulfur dioxide, nitrogen oxides, or greenhouse gases.

In the context of its regular country dialogue on energy and environmental issues, the World Bank is willing to assist its clients to develop the policy framework for implementing such environmental requirements for the power sector as a whole. One step in this process might be the preparation of a sectoral environmental assessment. This document assumes that the project is consistent with broad sectoral policies and requirements that have been promulgated by the relevant authorities in order to meet international obligations and other environmental goals affecting the power sector.

In some cases, strategies for meeting system-wide goals may be developed through a power-sector planning exercise that takes account of environmental and social factors. This would, for instance, be appropriate for a small country with a single integrated utility. In other cases, governments may decide to rely on a set of incentives and environmental standards designed to influence the decisions made by many independent operators.

Determining Site-Specific Requirements

This document spells out the process—starting from a set of maximum emissions levels acceptable to the World Bank Group—that should be followed in determining the site-specific emissions guidelines. The guidelines could encompass both controls on the plant and other measures, perhaps outside the plant, that may be necessary to mitigate the impact of the plant on the airshed or watershed in which it is located. The process outlines how the World Bank Group's policy on Environmental Assessment (OP 4.01) for thermal power plants can be implemented. The guidelines are designed to protect human health; reduce mass loading to the environment to acceptable levels; achieve emissions levels based on commercially proven and widely used technologies; follow current regulatory and technology trends; be cost-effective; and promote the use of cleaner fuels and good-management practices that increase energy efficiency and productivity.

It is important to stress that the results of the environmental assessment (EA) are critical to defining many of the design parameters and other assumptions, such as location, fuel choice, and the like, required to develop the detailed specification of a project. The assessment results must be integrated with economic analyses of the key design options. Thus, it is essential that the work of preparing an environmental assessment be initiated during the early stages of project conception and design so that the initial results of the study can be used in subsequent stages of project development. It is not acceptable to prepare an environmental assessment that considers a small number of options in order to justify a predetermined set of design choices.

Evaluation of Project Alternatives

The EA should include an analysis of reasonable alternatives that meet the ultimate objective of the project. The assessment may lead to alternatives that are sounder, from an environmental, sociocultural, and economic point of view, than the originally proposed project. Alternatives need to be considered for various aspects of the system, including:

- Fuels used
- Power generation technologies
- Heat rejection systems
- Water supply or intakes
- Solid waste disposal systems
- Plant and sanitary waste discharge
- Engineering and pollution control equipment (see Annex B for some examples)
- Management systems.

The alternatives should be evaluated as a part of the conceptual design process. Those alternatives that provide cost-effective environmental management are preferred.

Clean Development Mechanism (CDM)

The Kyoto Protocol provisions allow for the use of the clean development mechanism (CDM), under which, beginning in 2000, greenhouse gas emissions from projects in non-Annex I countries that are certified by designated operating entities can be acquired by Annex I countries and credited against their emissions binding commitments. The availability of CDM financing may alter, in some cases, the choice of the least-cost project alternative. Once the CDM is enacted, it will be advisable to incorporate the following steps into the process of evaluating project alternatives:

- Identification and assessment of alternatives that are eligible for CDM-type financing (e.g., alternatives that are not economical without carbon offsets and whose incremental costs above the least-cost baseline alternative, taking account of local environmental externalities, are smaller than the costs of resulting carbon offsets).
- Negotiation with Annex I parties of possible offset arrangements, if CDM-eligible alternatives exist. The World Bank Group will be prepared to assist in the process of identifying the CDM-eligible alternatives and negotiating offset arrangements for projects that are partly financed or guaranteed by the World Bank Group.

Environmental Assessment

An EA should be carried out early in the project cycle in order to establish emissions requirements and other measures on a site-specific basis for a new thermal power plant or unit of 50 MWe or larger. The initial tasks in carrying out the EA should include:

- Collection of baseline data on ambient concentrations of PM_{10} and sulfur oxides (for oil and coal-fired plants), nitrogen oxides, (and ground-level ozone, if levels of ambient exposure to ozone are thought to be a problem) within a defined airshed encompassing the proposed project.[2]
- Collection of similar baseline data for critical water quality indicators that might be affected by the plant.
- Use of appropriate air quality and dispersion models to estimate the impact of the project on the ambient concentrations of these pollutants, on the assumption that the maximum emissions levels described below apply. (See the chapters on airshed models in Part II of this *Handbook*.)

When there is a reasonable likelihood that in the medium or long term the power plant will be expanded or other pollution sources will increase significantly, the analysis should take account of the impact of the proposed plant design both immediately and after any probable expansion in capacity or in other sources of pollution. The EA should also include impacts from construction work and other activities that normally occur, such as migration of workers when large facilities are built. Plant design should allow for future installation of additional pollution control equipment, should this prove desirable or necessary.

The EA should also address other project-specific environmental concerns, such as emissions of cadmium, mercury, and other heavy metals resulting from burning certain types of coal or heavy fuel oil. If emissions of this kind are a concern, the government (or the project sponsor) and the World Bank Group will agree on specific measures for mitigating the impact of such emissions and on the associated emissions guidelines.

The quality of the EA (including systematic cost estimates) is likely to have a major influence on the ease and speed of project preparation. A good EA prepared early in the project cycle should make a significant contribution to keeping the overall costs of the project down.

Emissions Guidelines

Emissions levels for the design and operation of each project must be established through the EA process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook*, as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group.

The following maximum emissions levels are normally acceptable to the World Bank Group in making decisions regarding the provision of World Bank Group assistance for new fossil-fuel-fired thermal power plants or units of 50 MWe or larger (using conventional fuels). The emissions levels have been set so they can be achieved by adopting a variety of cost-effective options or technologies, including the use of clean fuels or washed coal. For example, dust controls capable of over 99% removal efficiency, such as electrostatic precipitators (ESPs) or baghouses, should always be installed for coal-fired power plants. Similarly, the use of low-NO_x burners with other combustion modifications such as low excess air (LEA) firing should be standard practice. The range of options for the control of sulfur oxides is greater because of large differences in the sulfur content of different fuels and in control costs. In general, for low-sulfur (less than 1% S), high-calorific-value fuels, specific controls may not be required, while coal cleaning, when feasible, or sorbent injection (in that order) may be adequate for medium-sulfur fuels (1–3% S). FGD may be considered for high-sulfur fuels (more than 3% S). Fluidized-bed combustion, when technically and economically feasible, has relatively low SO_x emissions. The choice of technology depends on a benefit-cost analysis of the environmental performance of different fuels and the cost of controls.

Any deviations from the following emissions levels must be described in the World Bank Group project documentation.

Air Emissions

The maximum emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems. In contrast, poor operating or maintenance procedures affect actual pollutant removal efficiency and may reduce it to well below the design specification. The maximum emissions levels are expressed as concentrations to facilitate monitoring. Dilution of air emissions to achieve these guidelines is unacceptable. Compliance with ambient air quality guidelines should be assessed on the basis of good engineering practice (GEP) recommendations. See Annex C for ambient air quality guidelines to be applied if local standards have not been set.[3] Plants should not use stack heights less than the GEP recommended values unless the air quality impact analysis has taken into account building downwash effects. All of the maximum emissions levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.[4] The remaining 5% of annual operating hours is assumed to be for start-up, shutdown, emergency fuel use, and unexpected incidents. For peaking units where the start-up mode is expected to be longer than 5% of the annual operating hours, exceedance should be justified by the EA with regard to air quality impacts.

Power plants in degraded airsheds. The following definitions apply in airsheds where there already exists a significant level of pollution.

An airshed will be classified as having *moderate air quality* with respect to particulates, sulfur dioxide, or nitrogen dioxide if either 1 or 2 applies:

1. (a) The annual mean value of PM_{10} exceeds 50 micrograms per cubic meter ($\mu g/m^3$) for the airshed (80 $\mu g/m^3$ for total suspended particulates, TSP); (b) the annual mean value of sulfur dioxide exceeds 50 $\mu g/m^3$; or (c) the annual mean value of nitrogen dioxide exceeds 100 $\mu g/m^3$ for the airshed.

2. The 98th percentile of 24-hour mean values of PM_{10}, sulfur dioxide, or nitrogen dioxide for the airshed over a period of a year exceeds 150 $\mu g/m^3$ (230 $\mu g/m^3$ for TSP).

An airshed will be classified as having *poor air quality* with respect to particulates, sulfur dioxide, or nitrogen dioxide if either 1 or 2 applies:

1. (a) The annual mean of PM_{10} exceeds 100 $\mu g/m^3$ for the airshed (160 $\mu g/m^3$ for TSP); (b) the annual mean of sulfur dioxide exceeds 100 $\mu g/m^3$ for the airshed; or (c) the annual mean of nitrogen dioxide exceeds 200 $\mu g/m^3$ for the airshed.

2. The 95th percentile of 24-hour mean values of PM_{10}, sulfur dioxide, or nitrogen dioxide for the airshed over a period of a year exceeds 150 $\mu g/m^3$ (230 $\mu g/m^3$ for TSP).

Plants smaller than 500 MWe in airsheds with moderate air quality are subject to the maximum emissions levels indicated below, provided that the EA shows that the plan will not lead *either* to the airshed dropping into the "poor air quality" category *or* to an increase of more than 5 $\mu g/m^3$ in the annual mean level of particulates (PM_{10} or TSP), sulfur dioxide, or nitrogen dioxide for the entire airshed. If either of these conditions is not satisfied, lower site-specific emissions levels should be established that would ensure that the conditions can be satisfied. The limit of a 5 $\mu g/m^3$ increase in the annual mean will apply to the cumulative total impact of all power plants built in the airshed within any 10-year period beginning on or after the date at which the guidelines come into effect.

Plants larger than or equal to 500 MWe in airsheds with moderate air quality and all plants in airsheds with poor air quality are subject to site-specific requirements that include offset provisions to ensure that (a) there is no net increase in the total emissions of particulates or sulfur dioxide within the airshed and (b) the resultant ambient levels of nitrogen dioxide do not exceed the levels specified for moderately degraded airsheds.[5] The measures agreed under the offset provisions must be implemented before the power plant comes fully on stream. Suitable offset measures could include reductions in emissions of particulates, sulfur dioxide, or nitrogen dioxide as a result of (a) the installation of new or more effective controls at other units within the same power plant or at other power plants in the same airshed, (b) the installation of new or more effective controls at other large sources, such as district heating plants or industrial plants, in the same airshed, or (c) investments in gas distribution or district heating systems designed to substitute for the use of coal for residential heating and other small boilers.[6] The monitoring and enforcement of the offset provisions would be the responsibility of the local or national agency responsible for granting and supervising environmental permits. Such offset provisions would normally be described in detail in a specific covenant in the project loan agreement.

Project sponsors who do not wish to engage in the negotiations necessary to put together an offset agreement would have the option of relying on an appropriate combination of clean fuels, controls, or both.

Particulate matter. For all plants or units, PM emissions (all sizes) should not exceed 50 mg/Nm^3.[7] The EA should pay specific attention to particulates smaller than 10 μm in aerodynamic diameter (PM_{10}) in the airshed, since these are inhaled into the lungs and are associated with the most serious effects on human health. Where possible, ambient levels of fine particulates (less than 2.5 mm in diameter) should be measured. Recent epidemiologic evidence suggests that much of the health damage caused by exposure to particulates is associated with these fine particles, which penetrate most deeply into the lungs. Emissions of PM_{10} and fine particulates include ash, soot, and carbon compounds (often the results of incomplete combustion), acid condensates, sulfates, and nitrates, as well as lead, cadmium, and other metals. Fine particulates, including sulfates, nitrates, and carbon compounds, are also formed by chemical processes in the atmosphere, but they tend to disperse over the whole airshed.

Sulfur dioxide. Total sulfur dioxide emissions from the power plant or unit should be less than 0.20 metric tons per day (tpd) per MWe of capacity for the first 500 MWe, plus 0.10 tpd for each additional MWe of capacity over 500 MWe.[8] In addition, the concentration of sulfur dioxide in flue gases should not exceed 2,000 mg/Nm^3 (see note 4 for assumptions), with a maximum emissions level of 500 tpd. Construction of two or more separate plants in the same airshed to circumvent this cap is not acceptable.

Nitrogen oxides. The specific emissions limits for nitrogen oxides are 750 mg/Nm^3, or 260 nanograms per joule (ng/J), or 365 parts per million parts (ppm) for a coal-fired power plant, and up to 1,500 mg/Nm^3 for plants using coal with volatile matter less than 10%; 460 mg/Nm^3 (or 130 ng/J, or 225 ppm) for an oil-fired power plant; and 320 mg/Nm^3 (or 86 ng/J, or 155 ppm) for a gas-fired power plant.

For combustion turbine units, the maximum NO_x emissions levels are 125 mg/Nm^3 (dry at 15% oxygen) for gas; 165 mg/Nm^3 (dry at 15% oxygen) for diesel (No. 2 oil); and 300 mg/Nm^3 (dry at 15% oxygen) for fuel oil (No. 6 and others).[9] Where there are technical difficulties, such as scarcity of water available for water injection, an emissions variance allowing a maximum emissions level of up to 400 mg/Nm^3 dry (at 15% oxygen) is considered acceptable, provided there are no significant environmental concerns associated with ambient levels of ozone or nitrogen dioxide.

For engine-driven power plants, the EA should pay particular attention to levels of nitrogen oxides before and after the completion of the project. Provided that the resultant maximum ambient levels of nitrogen dioxide are less than 150 µg/m^3 (24-hour average), the specific emissions guidelines are as follows: (a) for funding applications received after July 1, 2000, the NO_x emissions levels should be less than 2,000 mg/Nm^3 (or 13 grams per kilowatt-hour, g/kWh dry at 15% oxygen); and (b) for funding applications received before July 1, 2000, the NO_x emissions levels should be less than 2,300 mg/Nm^3 (or 17 g/kWh dry at 15% oxygen). In all other cases, the maximum emissions level of nitrogen oxides is 400 mg/Nm^3 (dry at 15% oxygen).

Offsets and the role of the World Bank Group. Large power complexes should normally not be developed in airsheds with moderate or poor air quality, or, if they must be developed, then only with appropriate offset measures. The costs of identifying and negotiating offsets for large power complexes are not large in relation to the total cost of preparing such projects. In the context of its regular country dialogue on energy and environmental issues, the World Bank is prepared to assist the process of formulating and implementing offset agreements for projects that are partly financed or guaranteed by the World Bank Group. If the offsets for a particular power project that will be financed by a World Bank Group loan involve specific investments to reduce emissions of particulates, sulfur oxides, or nitrogen oxides, these may be included within the scope of the project and may thus be eligible for financing under the loan.[10]

Long-range transport of acid pollutants. Where ground-level ozone or acidification is or may in future be a significant problem, governments are encouraged to undertake regional or national studies of the impact of sulfur dioxide, nitrogen oxides, and other pollutants that damage sensitive ecosystems, with, in appropriate cases, support from the World Bank (see Policy Framework, above). The aim of such studies is to identify least-cost options for reducing total emissions of these pollutants from a region or a country so as to achieve load targets, as appropriate.[11]

A possible (but not the only) approach to identifying sensitive ecosystems is to estimate critical loads for acid depositions and critical levels for ozone in different geographic areas. The analysis must, however, take into account the large degree of uncertainty involved in making such estimates.

In appropriate cases, governments should develop cost-effective strategies, as well as legal instruments, to protect sensitive ecosystems or to reduce transboundary flows of pollutants.

Where such regional studies have been carried out, the environmental assessment should take account of their results in assessing the overall impact of a proposed power plant.

The site-specific emissions requirements should be consistent with any strategy and applicable legal framework that have been adopted by the host country government to protect sensitive ecosystems or to reduce transboundary flows of pollutants.

Liquid Effluents

The effluent levels presented in Table 1 (for the applicable parameters) should be achieved daily without dilution.

Coal pile runoff and leachate may contain significant concentrations of toxics such as heavy metals. Where leaching of toxics to groundwater or their transport in surface runoff is a concern, suitable preventive and control measures such as protective liners and collection and treatment of runoff should be put in place.

Solid Wastes

Solid wastes, including ash and FGD sludges, that do not leach toxic substances or other contaminants of concern to the environment may be disposed in landfills or other disposal sites provided that they do not impact nearby water bodies. Where toxics or other contaminants are expected to leach out, they should be treated by, for example, stabilization before disposal.

Table 1. Effluents from Thermal Power Plants
(milligrams per liter, except for pH and temperature)

Parameter	*Maximum value*
pH	6–9
TSS	50
Oil and grease	10
Total residual chlorine[a]	0.2
Chromium (total)	0.5
Copper	0.5
Iron	1.0
Zinc	1.0
Temperature increase	≤ 3°C[b]

a. "Chlorine shocking" may be preferable in certain circumstances. This involves using high chlorine levels for a few seconds rather than a continuous low-level release. The maximum value is 2 mg/l for up to 2 hours, not to be repeated more frequently than once in 24 hours, with a 24-hour average of 0.2 mg/l. (The same limits would apply to bromine and fluorine.)
b. The effluent should result in a temperature increase of no more than 3° C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge when there are no sensitive aquatic ecosystems within this distance.

Ambient Noise

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise receptors located outside the project property boundary.

	Maximum allowable log equivalent (hourly measurements), in dB(A)	
Receptor	*Day (07:00–22:00)*	*Night (22:00–07:00)*
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Monitoring and Reporting

For measurement methods, see the chapter on Monitoring in this *Handbook*.

Maintaining the combustion temperature and the excess oxygen level within the optimal band in which particulate matter and NO_x emissions are minimized simultaneously ensures the greatest energy efficiency and the most economic plant operation. Monitoring should therefore aim at achieving this optimal performance as consistently as possible. Systems for continuous monitoring of particulate matter, sulfur oxides, and nitrogen oxides in the stack exhaust can be installed and are desirable whenever their maintenance and calibration can be ensured. Alternatively, surrogate performance monitoring should be performed on the basis of initial calibration. The following surrogate parameters are relevant for assessing environmental performance. (They require no changes in plant design but do call for appropriate training of operating personnel.)

- *Particulate matter.* Ash and heavy metal content of fuel; maximum flue gas flow rate; minimum power supply to the ESP or minimum pressure drop across the baghouse; minimum combustion temperature; and minimum excess oxygen level.
- *Sulfur dioxide.* Sulfur content of fuel.
- *Nitrogen oxides.* Maximum combustion temperature and maximum excess oxygen level.

Direct measurement of the concentrations of emissions in samples of flue gases should be performed regularly (for example, on an annual basis) to validate surrogate monitoring results or for the calibration of the continuous monitor (if used). The samples should be monitored for PM and nitrogen oxides and may be monitored for sulfur oxides and heavy metals, although monitoring the sulfur and heavy metal content of fuel is considered adequate. At least three data sets for direct emissions measurements should be used, based on an hourly rolling average.

Automatic air quality monitoring systems measuring ambient levels of PM_{10}, sulfur oxides, and nitrogen oxides outside the plant boundary should be installed where maximum ambient concentration is expected or where there are sensitive receptors such as protected areas and population centers. (PM_{10} and SO_x measurements are, however, not required for gas-fired plants.) The number of air quality monitors should be greater if the area in which the power plant is located is prone to temperature inversions or other meteorological conditions that lead to high levels of air pollutants affecting nearby populations or sensitive ecosystems. The purpose of such ambient air quality monitoring is to help assess the possible need for changes in operating practices (including burning cleaner fuels to avoid high short-term exposures), especially during periods of adverse meteorological conditions. The pollutant guidelines specify short-term ambient air quality guideline values which, if exceeded, call for emergency measures such as burning cleaner fuels.

Any measures should be taken in close collaboration with local authorities. The specific design of the ambient monitoring system should be based on the findings of the EA. The frequency of ambient measurements depends on prevailing conditions; ambient measurements, when taken, should normally be averaged daily.

The pH and temperature of the wastewater discharges should be monitored continuously. Levels of suspended solids, oil and grease, and residual chlorine should be measured daily, and heavy metals and other pollutants in wastewater discharges should be measured monthly if treatment is provided.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. The results should be reported in summary form, with notification of exceptions, if any, to the responsible government authorities and relevant parties, as required. In the absence of specific national or local government guidelines, actual monitoring or surrogate performance data should be reported at least annually. The government may require additional explanation and may take corrective action if plants are found to exceed maximum emissions levels for more than 5% of the operating time, or on the occasion of a plant audit. The objective is to ensure continuing compliance with the emissions limits agreed at the outset, based on sound operation and maintenance. Exceedances of the maximum emissions levels would normally be reviewed in light of the enterprise's good-faith efforts in this regard.

As part of the Framework Convention on Climate Change, countries will be asked to record their emissions of greenhouse gases (GHG). As an input to this, and to facilitate possible future activities implemented jointly with Annex I countries, the emissions of individual projects should be estimated on the basis of the chemical composition of the fuel or measured directly. Table 2 in the chapter on Greenhouse Gas Abatement and Climate Change in Part II of this *Handbook* provides relevant emissions factors.

In order to develop institutional capacity, training should be provided with adequate budgets to ensure satisfactory environmental performance. The training may include education on environmental assessment, environmental mitigation plans, and environmental monitoring. In some cases, it may be appropriate to include the staff from the environmental implementation agencies, such as the state pollution control board, in the training program

Key Issues

The key production and emissions control practices that will lead to compliance with the above guidelines are summarized below. It is assumed that the proposed project represents a least-cost solution, taking into account environmental and social factors.

- Choose the cleanest fuel economically available (natural gas is preferable to oil, which is preferable to coal).
- Give preference to high-heat-content, low-ash, low-sulfur coal (or high-heat-content, high-sulfur coal, in that order) and consider beneficiation for high-ash, high-sulfur coal.
- Select the best power generation technology for the fuel chosen to balance the environmental and economic benefits. The choice of technology and pollution control systems will be based on the site-specific environmental assessment.
- Keep in mind that particulates smaller than 10 microns in size are most important from a health perspective. Acceptable levels of particulate matter removal are achievable at relatively low cost.
- Consider cost-effective technologies such as pre-ESP sorbent injection, along with coal washing, before in-stack removal of sulfur dioxide.
- Use low-NO_x burners and other combustion modifications to reduce emissions of nitrogen oxides.
- Before adopting expensive control technologies, consider using offsetting reductions in emissions of critical pollutants at other sources within the airshed to achieve acceptable ambient levels.
- Use SO_x removal systems that generate less wastewater, if feasible; however, the environmental and cost characteristics of both inputs and wastes should be assessed case by case.
- Manage ash disposal and reclamation so as to minimize environmental impacts—especially the migration of toxic metals, if present, to nearby surface and groundwater bodies, in addition to the transport of suspended solids in surface runoff. Consider reusing ash for building materials.
- Consider recirculating cooling systems where thermal discharge to water bodies may be of concern.
- Note that a comprehensive monitoring and reporting system is required.

Annex A. Engine-Driven Power Plants

Engine-driven power plants use fuels such as diesel oil, fuel oil, gas, orimulsion, and crude oil. The two types of engines normally used are the medium-speed four-stroke trunk piston engine and the low-speed two-stroke crosshead engine. Both types of engine operate on the air-standard diesel thermodynamic cycle. Air is drawn or forced into a cylinder and is compressed by a piston. Fuel is injected into the cylinder and is ignited by the heat of the compression of the air. The burning mixture of fuel and air expands, pushing the piston. Finally the products of combustion are removed from the cylinder, completing the cycle. The energy released from the combustion of fuel is used to drive an engine, which rotates the shaft of an alternator to generate electricity. The combustion process typically includes preheating the fuel to the required viscosity, typically 16–20 centiStokes (cSt), for good fuel atomization at the nozzle. The fuel pressure is boosted to about 1,300 bar to achieve a droplet distribution small enough for fast combustion and low smoke values. The nozzle design is critical to the ignition and combustion process. Fuel spray penetrating to the liner can damage the liner and cause smoke formation. Spray in the vicinity of the valves may increase the valve temperature and contribute to hot corrosion and burned valves. If the fuel timing is too early, the cylinder pressure will increase, resulting in higher nitrogen oxide formation. If injection is timed too late, fuel consumption and turbocharger speed will increase. NO_x emissions can be reduced by later injection timing, but then particulate matter and the amount of unburned species will increase.

Ignition quality. For distillate fuels, methods for establishing ignition quality include cetane number and cetane index for diesel. The CCAI number, based on fuel density and viscosity, gives a rough indication of the ignition behavior of heavy fuel oil.

Fuel quality. Fuel ash constituents may lead to abrasive wear, deposit formation, and high-temperature corrosion, in addition to emissions of particulate matter. The properties of fuel that may affect engine operation include viscosity, specific gravity, stability (poor stability results in the precipitation of sludge, which may block the filters), cetane number, asphaltene content, carbon residue, sulfur content, vanadium and sodium content (an indicator of corrosion, especially on exhaust valves), presence of solids such as rust, sand, and aluminum silicate, which may result in blockage of fuel pumps and liner wear, and water content.

Waste characteristics. The wastes generated are typical of those from combustion processes. The exhaust gases contain particulates (including heavy metals if present in the fuel), sulfur and nitrogen oxides, and, in some cases, VOCs. Nitrogen oxides are the main concern after particulate matter in the air emissions. NO_x emissions levels are (almost exponentially) dependent on the temperature of combustion, in addition to other factors. Most of the NO_x emissions are formed from the air used for combustion and typically range from 1,100 to 2,000 ppm at 15% oxygen. Carbon dioxide emissions are approximately 600 g/kWh of electricity, and total hydrocarbons (calculated as methane equivalent) are 0.5 g/kWh of electricity.

The exhaust gases from an engine are affected by (a) the load profile of the prime mover; (b) ambient conditions such as air humidity and temperature; (c) fuel oil quality, such as sulfur content, nitrogen content, viscosity, ignition ability, density, and ash content; and (d) site conditions and the auxiliary equipment associated with the prime mover, such as cooling properties and exhaust gas back pressure. The engine parameters that affect nitrogen oxide emissions are (a) fuel injection in terms of timing, duration, and atomization; (b) combustion air conditions, which are affected by valve timing, the charge air system, and charge air cooling before cylinders; and (c) the combustion process, which is affected by air and fuel mixing, combustion chamber design, and the compression ratio. The particulate matter emissions are dependent on the general conditions of the engine, especially the fuel injection system and its maintenance, in addition to the ash content of the fuel, which is in the range 0.05–0.2%. SO_x emissions are directly dependent on the sulfur content of the fuel. Fuel oil may contain around 0.3% sulfur and, in some cases, up to 5%.

Annex B. Illustrative Pollution Prevention and Control Technologies

A wide variety of control technology options is available. As usual, these options should be considered after an adequate assessment of broader policy options, including pricing and institutional measures. Additional information is provided in the relevant documents on pollution control technologies.

Cleaner Fuels

The simplest and, in many circumstances, most cost-effective form of pollution prevention is to use cleaner fuels. For new power plants, combined-cycle plants burning natural gas currently have a decisive advantage in terms of their capital costs, thermal efficiency, and environmental performance. Natural gas is also the preferred fuel for minimizing GHG emissions because it produces lower carbon dioxide emissions per unit of energy and enhances energy efficiency.

If availability or price rule out natural gas as an option, the use of low-sulfur fuel oil or high-heat-content, low-sulfur, low-ash coal should be considered. Typically, such fuels command a premium price over their dirtier equivalents, but the reductions in operating or environmental costs that they permit are likely to outweigh this premium. In preparing projects, an evaluation of alternative fuel options should be conducted at the outset to establish the most cost-effective combination of fuel, technology, and environmental controls for meeting performance and environmental objectives.

If coal is used, optimal environmental performance and economic efficiency will be achieved through an integrated approach across the whole coal-energy chain, including the policy and investment aspects of mining, preparation, transport, power generation and heat conversion, and clean coal technologies. Coal washing, in particular, has a beneficial impact in terms of reducing the ash content and ash variability of coal used in thermal power plants, which leads to consistent boiler performance, reduced emissions, and less maintenance.

Abatement of Particulate Matter

The options for removing particulates from exhaust gases are cyclones, baghouses (fabric filters), and ESPs. Cyclones may be adequate as precleaning devices; they have an overall removal efficiency of less than 90% for all particulate matter and considerably lower for PM_{10}. Baghouses can achieve removal efficiencies of 99.9% or better for particulate matter of all sizes, and they have the potential to enhance the removal of sulfur oxides when sorbent injection, dry-scrubbing, or spray dryer absorption systems are used. ESPs are available in a broad range of sizes for power plants and can achieve removal efficiencies of 99.9% or better for particulate matter of all sizes.

The choice between a baghouse and an ESP will depend on fuel and ash characteristics, as well as on operating and environmental factors. ESPs can be less sensitive to plant upsets than fabric filters because their operating effectiveness is not as sensitive to maximum temperatures and they have a low pressure drop. However, ESP performance can be affected by fuel characteristics. Modern baghouses can be designed to achieve very high removal efficiencies for PM_{10} at a capital cost that is comparable to that for ESPs, but it is necessary to ensure appropriate training of operating and maintenance staff.

Abatement of Sulfur Oxides

The range of options and removal efficiencies for SO_x controls is wide. Pre-ESP sorbent injection can remove 30–70% of sulfur oxides, at a cost of US$50–$100 per kW. Post-ESP sorbent injection can achieve 70–90% SO_x removal, at a cost of US$80–$170 per kW. Wet and semidry FGD units consisting of dedicated SO_x absorbers can remove 70–95%, at a cost of US$80–$170 per kW (1997 prices). The operating costs of most FGDs are substantial because of the power consumed (of the order of 1–2% of the electricity generated), the chemicals used, and disposal of residues. Estimates by the International Energy Agency (IEA) suggest that the extra levelized annual cost for adding to a coal-fired power plant an FGD designed to remove 90% of sulfur oxides amounts to 10–14% depending on capacity utilization.

An integrated pollution management approach should be adopted that does not involve switching from one form of pollution to another. For example, FGD scrubber wastes, when improperly managed, can lead to contamination of the water supply, and such SO_x removal systems could result in greater emissions of particulate matter from materials handling and windblown dust. This suggests the need for careful benefit-cost analysis of the types and extent of SO_x abatement.

Abatement of Nitrogen Oxides

The main options for controlling NO_x emissions are combustion modifications: low-NO_x burners with or without overfire air or reburning, water/steam injection, and selective catalytic or noncatalytic reduction (SCR/SNCR). Combustion modifications can remove 30–70% of nitrogen oxides, at a capital cost of less than US$20 per kW and a small increase in operating costs. SNCR systems can remove 30–70% of nitrogen oxides, at a capital cost of US$20–$40 per kW and a moderate increase in operating cost. However, plugging of the preheater because of the formation of ammonium bisulfate may pose some problems. SCR units can remove 70–90% of nitrogen oxides but involve a much larger capital cost of US$40–$80 per kW and a significant increase in operating costs, especially for coal-fired plants. Moreover, SCR may require low-sulfur fuels (less than 1.5% sulfur content) because the catalyst elements are sensitive to the sulfur dioxide content in the flue gas.

Fly Ash Handling

Fly ash handling systems may be generally categorized as dry or wet, even though the dry handling system involves wetting the ash to 10–20% moisture to improve handling characteristics and to mitigate the dust generated during disposal. In wet systems, the ash is mixed with water to produce a liquid slurry containing 5–10% solids by weight. This is discharged to settling ponds, often with bottom ash and FGD sludges, as well. The ponds may be used as the final disposal site, or the settled solids may be dredged and removed for final disposal in a landfill. Wherever feasible, decanted water from ash disposal ponds should be recycled to formulate ash slurry. Where heavy metals are pre-sent in ash residues or FGD sludges, care must be taken to monitor and treat leachates and overflows from settling ponds, in addition to disposing of them in lined places to avoid contamination of water bodies. In some cases, ash residues are being used for building materials and in road construction. Gradual reclamation of ash ponds should be practiced.

Water Use

It is possible to reduce the fresh water intake for cooling systems by installing evaporative recirculating cooling systems. Such systems require a greater capital investment, but they may use only 5% of the water volume required for once-through cooling systems. Where once-through cooling systems are used, the volume of water required and the impact of its discharge can be reduced by careful siting of intakes and outfalls, by minimizing the use of biocides and anticorrosion chemicals (effective nonchromium-based alternatives are available to inhibit scale and products of corrosion in cooling water systems), and by controlling discharge temperatures and thermal plumes. Wastewaters from other processes, including boiler blowdown, demineralizer backwash, and resin regenerator wastewater, can also be recycled, but again, this requires careful management and treatment for reuse. Water use can also be reduced in certain circumstances through the use of air-cooled condensers.

Annex C. Ambient Air Quality

The guidelines presented in Table C.1 are to be used only for carrying out an environment assessment in the absence of local ambient standards. They were constructed as consensus values taking particular account of WHO, USEPA, and EU standards and guidelines. *They do not in any way substitute for a country's own ambient air quality standards.*

Table C.1. Ambient Air Quality in Thermal Power Plants
(micrograms per cubic meter)

Pollutant	*24-hour average*	*Annual average*
PM_{10}	150	50
TSP[a]	230	80
Nitrogen dioxide	150	100
Sulfur dioxide	150	80

a. Measurement of PM_{10} is preferable to measurement of TSP.

Notes

1. For plants smaller than 50 MWe, including those burning nonfossil fuels, PM emissions levels may be as much as 100 mg/Nm³. If justified by the EA, PM emissions levels up to 150 mg/Nm³ may be acceptable in special circumstances. The maximum emissions levels for nitrogen oxides remain the same, while for sulfur dioxide, the maximum emissions level is 2,000 mg/Nm³.

2. *Airshed* refers to the local area around the plant whose ambient air quality is directly affected by emissions from the plant. The size of the relevant local airshed will depend on plant characteristics, such as stack height, as well as on local meteorological conditions and topography. In some cases, airsheds are defined in legislation or by the relevant environmental authorities. If not, the EA should clearly define the airshed on the basis of consultations with those responsible for local environmental management.

In collecting baseline data, qualitative assessments may suffice for plants proposed in greenfield sites. For nondegraded airsheds, quantitative assessment using models and representative monitoring data may suffice.

3. See, e.g., United States, 40 CFR, Part 51, 100 (ii). Normally, GEP stack height = $H + 1.5L$, where H is the height of nearby structures and L is the lesser dimension of either height or projected width of nearby structures.

4. The assumptions are as follows: for coal, flue gas dry 6% excess oxygen—assumes 350 Nm³/GJ. For oil, flue gas dry 3% excess oxygen—assumes 280 Nm³/GJ. For gas, flue gas dry 3% excess oxygen—assumes 270 Nm³/GJ (see annex D). The oxygen level in engine exhausts and combustion turbines is assumed to be 15%, dry. See the document on Monitoring for measurement methods.

5. Gas-fired plants (in which the backup fuel contains less than 0.3% sulfur) and other plants that achieve emissions levels of less than 400 mg/Nm³ for sulfur oxides and nitrogen oxides are exempt from the offset requirements, since their emissions are relatively lower.

Annex D. Conversion Chart

Table D.1. SO_2 and NO_x Emissions Conversion Chart for Steam-Based Thermal Power Plants

To convert	*To (multiply by):*								
		ppm	*ppm*	*g/GJ*			*lb/10⁶ Btu*		
From	*Mg/Nm³*	*NO_x*	*SO_2*	*Coal*[a]	*Oil*[b]	*Gas*[c]	*Coal*[a]	*Oil*[b]	*Gas*[c]
Mg/Nm³	1	0.487	0.350	0.350	0.280	0.270	8.14 x 10-4	6.51 x 10-4	6.28 x 10-4
ppm NO_x	2.05	1		0.718	0.575	0.554	1.67 x 10-3	1.34 x 10-3	1.29 x 10-3
ppm SO_2	2.86		1	1.00	0.801	0.771	2.33 x 10-3	1.86 x 10-3	1.79 x 10-3
G/GJ									
Coal[a]	2.86	1.39	1.00	1			2.33 x 10-3		
Oil[b]	3.57	1.74	1.25		1			2.33 x 10-3	
Gas[c]	3.70	1.80	1.30			1			2.33 x 10-3
lb/10⁶ Btu									
Coal[a]	1,230	598	430	430			1		
Oil[b]	1,540	748	538		430			1	
Gas[c]	1,590	775	557			430			1

Note: g/GJ, grams per gigajoule; lb/10⁶ Btu, pounds per 100,000 British thermal units; Mg/Nm³, megagrams per normal cubic meter; ppm, parts per million.
a. Flue gas dry 6% excess O_2; assumes 350 Nm³/GJ.
b. Flue gas dry 3% excess O_2; assumes 280 Nm³/GJ.
c. Flue gas dry 3% excess O_2; assumes 270 Nm³/GJ.
Source: International Combustion Ltd.; data for coal, oil, and gas based on IEA 1986.

6. Wherever possible, the offset provisions should be implemented within the framework of an overall air quality management strategy designed to ensure that air quality in the airshed is brought into compliance with ambient standards.

7. A normal cubic meter (Nm³) is measured at 1 atmosphere and 0° C. The additional cost of controls designed to meet the 50 mg/Nm³ requirement, rather than one of 150 mg/Nm³ (e.g., less than 0.5% of total investment costs for a 600 MW plant) is expected to be less than the benefits of reducing ambient exposure to particulates. The high overall removal rate is necessary to capture PM_{10} and fine particulates that seriously affect human health. Typically about 40% of PM by mass is smaller than 10 μm, but the collection efficiency of ESPs drops considerably for smaller particles. A properly designed and well-operated plant can normally achieve the lower emissions levels as easily as it can achieve higher emissions levels.

An exception to the maximum PM emissions level may be granted to engine-driven power plants for which funding applications are received before January 1, 2001. PM emissions levels of up to 75 mg/Nm³ would be allowed, provided that the EA presents documentation to show that (a) lower-ash grades of fuel oil are not commercially available; (b) emissions control technologies are not commercially available; and (c) the resultant ambient levels for PM_{10} (annual average of less than 50 μg/m³ and 24-hour mean of less than 150 μg/m³) will be maintained for the entire duration of the project.

8. The maximum SO_x emissions levels were back-calculated using the U.S. Environmental Protection Agency Industrial Source Complex (ISC) Model, with the objective of complying with the 1987 WHO Air Quality Guidelines for acceptable one-hour (peak) ambient concentration levels (350 μg/m³). The modeling results show that, in general, an emissions level of 2,000 mg/m³ (equivalent to 0.2 tpd per MWe) results in a one-hour level of 300 μg/m³, which, when added to a typical existing background level of 50 μg/m³ for greenfield sites, produces a one-hour level of 350 μg/m³ (see the discussion of degraded airsheds in the text). Compliance with the WHO one-hour level is normally the most significant, as short-term health impacts are considered to be the most important; compliance with this level also, in general, implies compliance with the WHO 24-hour and annual average guidelines. For large plants, the emissions guidelines for sulfur dioxide were further reduced to 0.1 tpd per MWe for capacities above 500 MWe to maintain acceptable mass loadings to the environment and thus address ecological concerns (acid rain). This results in a sulfur dioxide emissions level of 0.15 tpd/MWe (or 1.275 lb/mm Btu) for a 1,000 MWe plant.

9. Where the nitrogen content of the liquid fuel is greater than 0.015% and the selected equipment manufacturer cannot guarantee the emissions levels pro-

vided in the text, an NO_x emissions allowance (i.e., added to the maximum emissions level) can be computed based on the following data as exceptions:

Nitrogen content (percentage by weight)	*Correction factor (NO_x percentage by volume)*
0.015–0.1	0.04 N
0.1–0.25	0.004 + 0.0067 (N – 0.1)
> 0.25	0.005

Note: Correction factor, 0.004% = 40 ppm = 80 mg/ Nm^3.

There may be cases in which cost-effective NO_x controls may not be technically feasible. Exceptions to the NO_x emissions requirements (including those given in this note) are acceptable provided it can be shown that (a) for the entire duration of the project, the alternative emissions level will not result in ambient conditions that have a significant impact on human health and the environment, and (b) cost-effective techniques such as low-NO_x burners, LEA, water or steam injection, and reburning are not feasible.

10. It should be noted that the offset requirement, which focuses on the level of total emissions, should result in an improvement in ambient air quality within the airshed, compared with the baseline scenario (as documented with ambient air monitoring data), if the offset measures are implemented for non-power-plant sources. Such sources typically emit from stacks of a lower average height than those for the new power plant.

11. Part II of this *Handbook* provides guidance on possible approaches for dealing with acid emissions. There is substantial scope for exploiting the synergies between the local and long-range benefits of emissions reductions.

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Appendix F
World Bank: Thermal Power – Rehabilitation of Existing Plants

Key Issues

The range of circumstances in which the rehabilitation of an existing thermal power plant may be considered is extremely large. It is neither possible nor desirable to attempt to prescribe specific environmental guidelines for all of the different cases that may arise in the World Bank's operational work. Hence, this document focuses on the process that should be followed in order to arrive at an agreed set of site-specific standards that should be met by the plant after its rehabilitation.

At the heart of this process is the preparation of a combined environmental audit of the existing plant and assessment of alternative rehabilitation options relevant to the future impact of the plant on nearby populations and ecosystems. The coverage of the environmental assessment component of the study will depend on the rehabilitation activities involved and may be similar to that required for a new thermal power plant when major portions of the plant are being replaced or retrofitted. The amount of data required, the range of options considered, and the coverage of the environmental analysis will typically be less than appropriate for a new plant. At the same time, the initial environmental audit should not be restricted to those parts of the existing plant that may be affected by the rehabilitation. It should review all the major aspects of the plant's equipment and operating procedures in order to identify environmental problems and recommend cost-effective measures that would improve the plant's environmental performance.

The time and resources devoted to preparing the environmental audit and assessment should be appropriate to the nature and scale of the proposed rehabilitation. It would, for example, not be appropriate to carry out an extensive environmental assessment in cases involving minor modifications or the installation or upgrading of environmental controls such as a wastewater treatment plant or dust filters or precipitators. For larger projects, such as the installation of flue gas desulfurization (FGD) equipment, the environmental assessment might focus particularly on the range of options for reducing sulfur emissions and for disposing of the gypsum or solid waste generated by the equipment.

It is, however, recommended that an environmental audit be undertaken in almost all cases. Experience suggests that such investigations will often pay for themselves by identifying zero- or low-cost options for energy conservation and waste minimization. In addition, such an audit may indicate ways in which the project could be redesigned in order to address the most serious environmental problems associated with the plant.

Major rehabilitations that imply a substantial extension (10 years or more) of the expected operating life of the plant should be subject to an environmental assessment similar in depth and coverage to one that would be prepared for a new plant. In such cases, the plant will normally be expected to meet the basic guidelines that apply to new thermal power plants for emissions of particulates, nitrogen oxides (NO_x), wastewater discharges, and solid wastes. Where the rehabilitated plant would be unable to meet the basic guidelines for sulfur dioxide (SO_2) without additional and potentially expensive controls, the environmental assessment should review the full range of options for reducing SO_2 emissions, both from the plant itself and from other sources within the same airshed or elsewhere in the country. On the basis of this analysis, the government, the enterprise, and the World Bank Group will agree on specific measures, either at the plant or elsewhere, to mitigate the impact of these emissions and will also agree on the associated emissions requirements.

Any rehabilitation that involves a shift in fuel type—i.e., from coal or oil to gas, as distinguished from a change from one grade or quality of coal or oil to another—will be subject to the same basic emissions guidelines as would apply to a new plant burning the same fuel.

Environmental Audit

An audit of the environmental performance of the existing plant should do at least the following:

- Review the actual operating and environmental performance of the plant in relation to its original design parameters.
- Examine the reasons for poor performance to identify measures that should be taken to address specific problems or to provide a basis for more appropriate assumptions about operating conditions in the future—for example, with respect to average fuel characteristics.
- Assess the scope for making improvements in maintenance and housekeeping inside and around the plant (e.g., check for excess oxygen levels, actual emissions levels, fuel spills, coal pile runoff, fugitive dust from coal piles, recordkeeping, monitoring, and other indicators of operation and maintenance of thermal power plants).
- Evaluate the readiness and capacity of the plant's emergency management systems to cope with incidents varying from small spills to major accidents (check storage of flammables, safe boiler and air pollution control system operation, and so on).
- Examine the plant's record with respect to worker safety and occupational health.

The report on the environmental audit should provide recommendations on the measures required to rectify any serious problems that were identified in the course of the study. These recommendations should be accompanied by approximate estimates of the capital and operating costs that would be involved and by an indication of the actions that should be taken either to implement the recommendations or to evaluate alternative options.

The management of the plant or the borrower should submit the report on the environmental audit to the World Bank Group, along with a statement of the steps taken to address the problems that were identified and to ensure that such problems do not recur in the future. Implementation of the actions outlined in the statement will be treated as one of the elements of the site-specific requirements for the project.

Environmental Assessment

An environmental assessment of the proposed rehabilitation should be carried out early in the process of preparing the project in order to allow an opportunity to evaluate alternative rehabilitation options before key design decisions are finalized. The assessment should examine the impacts of the existing plant's operations on nearby populations and ecosystems, the changes in these impacts that would result under alternative specifications for the rehabilitation, and the estimated capital and operating costs associated with each option.

Depending on the scale and nature of the rehabilitation, the environmental assessment may be relatively narrow in scope, focusing on only a small number of specific concerns that would be affected by the project, or it may be as extensive as would be appropriate for the construction of a new unit at the same site. Normally, it should cover the following points:

- Ambient environmental quality in the airshed or water basin affected by the plant, together with approximate estimates of the contribution of the plant to total emissions loads of the main pollutants of concern
- The impact of the plant, under existing operating conditions and under alternative scenarios for rehabilitation, on ambient air and water quality affecting neighboring populations and sensitive ecosystems
- The likely costs of achieving alternative emissions standards or other environmental targets for the plant as a whole or for specific aspects of its operations
- Recommendations concerning a range of cost-effective measures for improving the environmental performance of the plant within the

framework of the rehabilitation project and any associated emissions standards or other requirements implied by the adoption of specific measures.

These issues should be covered at a level of detail appropriate to the nature and scale of the proposed project.

If the plant is located in an airshed or water basin that is polluted as a result of emissions from a range of sources, including the plant itself, comparisons should be made of the relative costs of improving ambient air or water quality by reducing emissions from the plant or by reducing emissions from other sources. As a result of such an analysis, the government, the enterprise, and the World Bank Group would agree to set site-specific emissions standards for the plant after it has been rehabilitated that take account of actions to reduce other emissions elsewhere in the airshed or water basin.

Emissions Guidelines

The following measures must be incorporated when rehabilitating thermal power plants:

- Normally, the energy conversion efficiency of the plant should be increased by at least 25% of its current level.
- Baseline emissions levels for particulate matter, nitrogen oxides, and sulfur oxides should be computed.
- An analysis of the feasibility (including benefits) of switching to a cleaner fuel should be conducted. Gas is preferred where its supply can be assured at or below world average prices. Coal with high heat content and low sulfur content is preferred over coal with high heat content and high sulfur content, which in turn is preferred over coal with low heat content and high sulfur content.
- Washed coal should be used, if feasible.
- Low-NO_x burners should be used, where feasible.
- Either the emissions levels recommended for new plants, or at least a 25% reduction in baseline level, should be achieved for the pollutant being addressed by the rehabilitation project.
- The maximum emissions level for PM is 100 milligrams per normal cubic meter (mg/Nm^3), but the target should be 50 mg/Nm^3. In rare cases, an emissions level of up to 150 mg/Nm^3 may be acceptable.
- SO_2 emissions levels should meet regional load targets. Cleaner fuels should be used, to avoid short-term exposure to sulfur dioxide.

Monitoring and Reporting

Monitoring and reporting requirements for a thermal power plant that has been rehabilitated should be the same as those for a new thermal power plant of similar size and fuel type.

Appendix G Flue Gas Emissions Standards for Coal-fired Power Plant (Chinese)

Pollutant		Phase I[1]		Phase II[2]		Phase III[3]		
		ESP	Other dedusters	>670tph or in urban areas	<670tph and in urban areas	Urban area	Rural area	Phase I
TSP, mg/Nm^3	Aar ≤10	200	800	150	500	200	500	600
	10<Aar≤20	300	1200	200	700			
	20<Aar≤25	500	1700	300	1000			
	25<Aar≤30	600	2100	350	1300			
	30<Aar≤35	700	2400	400	1500			
	35<Aar≤40	800	2800	450	1700			
	Aar>40	1000	3300	600	2000			
SO_2	tph	Calculate by the following formula, detail refer to GB13223-91 $Q_{SO_2} = PUH_e^m \times 10^{-6}; U = \overline{U}_{10}\left(\frac{H_s}{10}\right)^{0.15}, H_e = H_s + \Delta H$						
	mg/Nm^3	NA		NA		2100 if S^y≤1%; 1200 if S^y>1%		
NO_x	mg/Nm^3	NA		NA		650 if dry bottom ash; 1000 if liquid bottom ash		

Note:

1. **Phase I**: applies to thermal plants built or examined and approved for construction before August 1, 1992
2. **Phase II**: applies to plants built or examined for construction during between August 1, 1992 and December 31, 1996, and
3. **Phase III**: applies to plants built or approved for construction on or after January 1, 1997.

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