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16132

China
Efficient Industrial Boilers

Project Document
November 1996

THE WORLD BANK

GEF Documentation

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China

Efficient Industrial Boilers

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November 1996

Environment and Municipal Development Operations Division
China and Mongolia Department
East Asia and Pacific Regional Office

CURRENCY EQUIVALENTS

Currency Name - Renminbi
Currency Unit = Yuan (Y)
Y 1.00 = $0.12
$1.00 = Y 8.5

FISCAL YEAR

January 1 - December 31

WEIGHTS AND MEASURES

1 meter (m)	=	3.28 feet (ft)
1 cubic meter (m^3)	=	35.3 cubic feet
1 kilogram (kg)	=	2.2046 pounds (lbs)

ABBREVIATIONS AND ACRONYMS

BCEC	-	Beijing Clean Combustion Engineering Co. Ltd.
CAS	-	Country Assistance Strategy
CMIC	-	China Machine-Building International Corporation
CO_2	-	Carbon Dioxide
DBM	-	Domestic Boiler Manufacturer
FBC	-	Fluidized Bed Combustion
GEF	-	Global Environment Facility
GHG	-	Greenhouse Gas Emissions
IB	-	Industrial Boiler
IRR	-	Internal Rate of Return
LIB	-	Limited International Bidding
M&E	-	Monitoring and Evaluation
MMI	-	Ministry of Machinery Industry
MOF	-	Ministry of Finance
Mt	-	Million Tons
NEPA	-	National Environmental Protection Agency
NO_x	-	Nitrogen Oxides
PIP	-	Project Implementation Plan
PLG	-	Project Leading Group
PMO	-	Project Management Office
SO_2	-	Sulfur Dioxide
SOE	-	Statement of Expenditure
TA	-	Technical Assistance
tph	-	Tons Per Hour (Steam)
TSP	-	Total Suspended Particulates
TVE	-	Township and Village Enterprises

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This report is based on an appraisal mission that visited China in June/July 1996. The report was prepared by Neil Hughes (Senior Operations Officer and Task Manager), Lily Uy Hale (Operations Officer), Todd Johnson (Economist), Brooks Howell (Consultant/ Boiler Engineer), R. Gopalkrishnan (Procurement Specialist) and Ying Xiang (RMC/ Operations Officer). The peer reviewers are: Elaine Sun (Senior Financial Analyst), Roger Heath (Principal Chemical Engineer) and Jack Fritz (Environment/Energy Specialist).

PART I: PROJECT SUMMARY

CHINA

EFFICIENT INDUSTRIAL BOILERS

Country/Sector Background

1. Scientific evidence is mounting that a buildup in atmospheric concentrations of greenhouse gases (GHGs), especially carbon dioxide (CO_2) from fossil fuel consumption, is contributing to a warming of the Earth's atmosphere. In China, CO_2 from energy consumption accounts for roughly 80 percent of the country's GHG emissions, the largest single source of which is coal combustion in industrial boilers. Medium and small-scale industrial boilers (IBs)—defined as boilers which produce less than 65 tons of steam per hour (tph)—consumed over 350 million tons of coal in China in 1990, accounting for around 35 percent of the country's coal use and around 715 million tons of CO_2, equal to 30 percent of total GHG emissions from energy consumption. For comparison, power sector boilers consumed about 250 million tons of coal in 1990, accounting for one-quarter of total coal use and about one-fifth of GHG emissions from energy consumption.

2. There are an estimated half million IBs in use in China and unit sizes are small by international standards; over half of all IBs in China are between 1 and 4 tph, and the average size is only 2.3 tph. In contrast to other major industrial countries, where coal-fired boilers outside of the power sector have been largely phased out, over 95 percent of industrial boilers in China burn coal. Given the cost advantages of coal relative to oil, and the lack of large-scale supplies of gas in China, the use of large amounts of coal by small boilers will continue well into the next century.

3. The market for industrial boilers has grown significantly since 1978, closely paralleling the growth of the Chinese economy. The two most important sources of demand for industrial boilers are: (a) light and textile industries, which require process heat and power; and (b) space heating for individual apartment buildings, district residential areas (district heating), and commercial buildings, particularly in northern Chinese cities. Three regions of the country—North, Northeast, and East[1]—which represent economically active areas with growing space heating demands, accounted for 70.3 percent of total installed capacity in tph of industrial boilers in 1993. Given the expected future growth of light industry, township and village enterprises (TVEs) and an increase in the area of space heating in northern China, new and replacement boiler

[1] **North** China (Huabei) includes Hebei and Shanxi provinces, Inner Mongolia autonomous region, and Beijing municipality. **Northeast** China (Dongbei) includes Heilongjiang, Jilin, and Liaoning provinces. **East** China (Huadong) includes Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, and Shandong provinces.

annual demand is conservatively anticipated to rise by about 30 percent over the coming 15 years.[2]

4. Chinese industrial boiler designs and production methods are based on pre-1950 design principles. Typical efficiency levels for Chinese IBs lie in the range of 60-65 percent. Boilers of similar scale and application in developed countries rarely operate below 80 percent net efficiency. In developed countries, significant improvements in production techniques, materials, and auxiliary equipment (fans, stokers, controls) over the past three decades have resulted in significant improvements in the thermal efficiency of small and medium-sized industrial boilers. If the thermal efficiency of the current stock of IBs in China could be raised to those of similar sizes in the developed countries, coal consumption by small boilers could be reduced by 60 million tons per year—a savings of about 17 percent. Retrofitting existing boilers has been deemed insufficient for sustaining efficiency improvements in the sector, because: (a) the demand for new boiler technology in China is growing, making existing boilers an ever-smaller percentage of the total market; (b) the lifespan of a typical boiler in China today is only about 15 years; and (c) improved boiler production techniques are a critical aspect of raising thermal efficiency by minimizing exit gas temperature and excess air in the boiler.[3]

5. The desirability of improving the energy efficiency of industrial boilers is widely recognized in China, however, a variety of factors have prevented improvements from being realized. The current boiler production base was built up over a thirty-year period when the economy was characterized by command-and-control decisions, artificially low prices of coal, and a primary focus among enterprises on meeting or exceeding production quotas. The economic environment in China has changed significantly with the shift towards a market economy: (a) firms now have a profit incentive; (b) coal pricing is largely market-driven; and (c) environmental regulations have become increasingly more strict. Despite the importance of these changes for improving energy efficiency in China, especially over the longer term, additional measures are needed to hasten major efficiency improvements in China over the coming decade, when a large amount of new and replacement IB capacity will be added.

6. **Barriers to the Adoption of Energy Efficient Boilers.** Despite major advances in boiler technology worldwide over the past 40 years, China's industrial boiler industry has operated largely in isolation from the world market. Since 1980, major international companies have shown considerable interest in China's large-scale electric power boiler sector and, to a lesser extent, in medium-sized oil and gas-fired boilers. However, there has been a striking absence of interest in coal-fired IBs. Among the reasons are: (a) IB profit margins for international firms are low compared to the power boiler market;

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2 *Prefeasibility Study on High Efficiency Industrial Boilers*, China Greenhouse Gas Study, Subreport No. 11, August 1994.

3 *Prefeasibility Study on High Efficiency Industrial Boilers*, China Greenhouse Gas Study, Subreport No. 11, August 1994.

(b) product development is likely to take time, and be characterized by adaptation and integration, rather than sales of "off-the-shelf" components or package boilers; (c) unlike the power boiler market, improved IB designs could be more easily replicated and disseminated, thus forfeiting the ability to recoup development and investment costs; (d) the few international firms that continue to produce IBs are mostly small companies, and have been unwilling to become involved in China, due to perceived high risks and startup costs; and (e) there is little export potential for coal-fired IBs, and thus an inability to directly earn foreign exchange.

7. There are numerous domestic barriers, as well, on both the producer and consumer side: (a) the industry is in the midst of transition from plan to market, and production by about two dozen major producers and hundreds of smaller ones is still significantly below economic scale; (b) product marketing and customer service, basically nonexistent under the planned economy, are still weak, which has inhibited the introduction of new boiler models; (c) standards for thermal efficiency, coal quality, and environmental performance for IBs are out-of-date, and enforcement at the local level, while improving, continues to be difficult without clear incentives; (d) decentralized production and weak industry associations have resulted in a scarcity of information exchange within the industry; (e) low profitability in the industry, due to below-economic scale production, rising input costs, and intense competition in the small, low-technology end of the industry, has inhibited the development and marketing of new products; (f) the lack of consumer information on energy savings has inhibited demand for more efficient but higher-priced boilers, and without such information, consumers have shown a disinterest in purchasing energy-efficient boiler models unless there are other significant benefits, such as reduced local pollution emissions, ease of use, and increased safety; and (g) underdeveloped capital markets have been reluctant to lend to producers for domestically untested new products or to consumers for capital investments with payback periods of more than a few years. As a result of these factors, energy efficiency improvements in coal-fired industrial boilers in China over the past decade have been very modest, with minimal investment in product development and production line overhaul.

Project Identification

8. A *Prefeasibility Study of High Efficiency Boilers* (1994), carried out as part of the GEF-supported China Greenhouse Gas Study by the World Bank and the Chinese government, concludes that major improvements in the energy efficiency of Chinese industrial boilers can be achieved only through a systematic program of acquiring and demonstrating advanced international technologies in China, and by removing the barriers to widespread dissemination. As part of the prefeasibility study, the Ministry of Machinery Industry (MMI), with the assistance of international boiler experts and the Bank, conducted a detailed assessment of boiler producers and users in China, including future demand trends, and identified the IB technologies that will be most needed in both steam and hot water applications. In addition, market studies of China's industrial boiler industry were conducted by MMI's Project Planning and Research Institute in Hangzhou

in 1988, 1991, and 1994, and these studies have been used as the basis for determining the demand for the boiler models to be supported by the project, and for determining the price of the new boilers. The boiler models proposed for the GEF project (see Annex 1) represent about 70 percent of the current industrial boiler market in China, of which hot water, cogeneration, and fluidized bed combustion (FBC) boilers are expected to gain in market share in the future. The project enterprises will produce an estimated 27,000 tph of new boiler capacity by the year 2002, compared to an estimated total industrial boiler production for China around 105,000 tph.

Project Objectives

9. The principal objective of the GEF project is to reduce GHG emissions, as well as emissions of total suspended particulates (TSP), sulfur dioxide (SO_2) and nitrogen oxides (NO_x), through: (a) the development of affordable energy-efficient and cleaner IB designs; (b) the mass production and marketing of the improved boiler models that have successfully met performance criteria; and (c) the broad dissemination of more energy-efficient and cleaner IB technologies throughout China through institutional strengthening, improved information exchange, and energy efficiency and environmental policy reform.

Project Description

10. The project would be composed of the following components (estimated total project cost and GEF financing):

(a) **Upgrading of existing Chinese boiler models ($53.1 million, GEF contribution of $16.5 million)** through the introduction from abroad of advanced combustion systems and auxiliary equipment, especially the application of simple automatic controls. The following Chinese IB models, which currently account for about 60 percent of market demand in China, have been selected for improvement:

- packaged watertube boiler
- improved packaged firetube-watertube boiler
- modular watertube boiler
- high sulfur coal boiler
- packaged and modular hot water boiler
- packaged and modular extended furnace watertube-firetube boiler

(b) **Adoption of new high efficiency boiler models ($44.1 million, GEF contribution of $13.7 million)** through the introduction of modern manufacturing techniques and boiler designs suitable for burning Chinese coals. Three new boiler designs, which will occupy a growing share of China's IB market, are targeted for introduction under the project:

- medium capacity steam boiler (cogeneration)
- medium capacity hot water boiler (district heating boiler)
- fluidized bed combustion (FBC) boiler

(c) **Technical assistance (TA) and training for boiler producers and consumers ($2.1 million, GEF contribution of $1.3 million)**: (i) improve the quality of boiler operation in China through advanced training and by initiating steps for establishing an IB operation certification program; (ii) assist boiler producers develop marketing plans for improved boilers; (iii) establish a pilot program in three municipalities in China (Beijing, Chongqing and Harbin) to stimulate the demand for more efficient and cleaner IBs; (iv) strengthen customer service programs by domestic boiler manufacturers (DBMs); (v) disseminate successful boiler technologies to other boiler producers in China; (vi) revise national standards for thermal efficiency, environmental emissions, and coal quality for IBs; (vii) extend design improvements for IBs throughout China; and (viii) improve boiler standards for IB auxiliary equipment.

(d) **Monitoring and evaluation (M&E), and project management ($2.1 million, GEF contribution of $1.3 million)**: institutional strengthening will be provided to MMI and related companies and research institutes in order to effectively implement the project and upgrade long-term institutional capacity. Support would be provided to develop monitoring and evaluation systems, including provision of monitoring equipment and training of project management office (PMO) staff.

11. **Investment funding** would be provided to nine Chinese boiler manufacturing enterprises in two phases. Under Phase 1, GEF funds would be used to acquire advanced international technologies for new and existing Chinese IB models and produce the model IB units. At the end of Phase 1, the model units would be evaluated against agreed technical, environmental and safety performance indicators, while project enterprises would be required to show viable production, marketing and financing plans for Phase 2. Under Phase 2, GEF grant funds would be used to acquire advanced production equipment from abroad to upgrade their production lines, in order to mass produce the successful models. **TA and training** would be provided to the IB industry in China to improve boiler operation, to ensure effective dissemination and marketing of high-efficiency IB models, and to improve standards for thermal efficiency, coal supply, and pollution control for Chinese IBs.

Project Preparation

12. MMI is responsible for implementing this GEF project. PMO was established by MMI for coordinating all activities during project preparation and for preparing a project implementation plan (PIP). A GEF Block C grant of $746,000 was obtained for the

purposes of preparing the project and is being used for: (a) an international technology assessment and evaluation of potential international technology suppliers; (b) the prequalification and selection of DBMs; (c) financial and economic evaluation training for DBMs and PMO; (d) short- and long-term international technical and procurement specialists to assist in project preparation; and (e) other costs of project preparation activities through Board approval.

13. **Technical Review.** As required for GEF projects, this project was reviewed in December 1994 by an external technical reviewer from the GEF's Scientific and Technical Advisory Panel. The reviewer noted that the project offers significant potential for GHG reduction but that successful marketing and dissemination of the improved boilers would hinge not only upon energy efficiency, but on other attributes such as cost, pollution controls, ease of operation, and the provision of full service by the boiler manufacturers. These issues were addressed during project preparation, and have been incorporated into the present project design. In a second review in January 1996, the same reviewer noted the progress that had been made in addressing "sustainability" issues in the project design, including the need for customer service and the importance of meeting energy efficiency and environmental standards in the improved boiler designs.

14. **Stakeholder Identification.** During project identification and preparation, key stakeholders were identified (see Annex 8). The key stakeholders in the project are: (a) consumers or users of industrial boilers, both current and prospective; (b) industrial boiler manufacturers; (c) MMI, in setting design standards, regulating the manufacture of industrial boilers, and disseminating best-practice within the industry; (d) local governments involved in commissioning, testing, and monitoring industrial boilers for safety and environmental compliance; (e) domestic and international research institutes involved in design and testing of new boiler models; (f) international industrial boiler technology suppliers; and, (g) the Bank.

15. **Selection of Domestic Boiler Manufacturers (DBM).** The selection of DBMs to participate in the project was undertaken in two stages, i.e., prequalification and final selection, to ensure that enterprises met strict technical, financial, and commercial qualifications and to ensure "ownership" of the project. All boiler enterprises in China were notified about the project and of the opportunity to participate. Of 33 firms that submitted prefeasibility studies, 20 were prequalified and allowed to proceed to the feasibility study stage and final selection. Prequalified firms next participated in an international technology assessment tour to visit potential technology suppliers. Subsequently, these firms incorporated their initial technology acquisition needs into a feasibility study required for final selection. Both prequalification and final selection were carried out by PMO, with assistance from international boiler consultants and a local financial consultant in accordance with Bank-agreed criteria (see Annex 2). As a result, nine DBMs have been selected with the Bank's "no objection" to acquire the advanced technology outlined in para. 10 above.

16. **Role of DBMs and the Enterprise Group.** Each boiler subproject would involve design, demonstration testing, and manufacture of the new boiler by an enterprise group comprised of a leading enterprise (the DBM), one or more manufacturers of auxiliary boiler equipment, and as needed, a boiler design institute. The DBM would (a) receive the proceeds of the subgrant, (b) be responsible for implementation of the subproject, and (c) enter into arrangements with the auxiliary equipment manufacturers to assist in carrying out the subproject, including the procurement of appropriate auxiliary equipment technology.

Associated Investment Project

17. The GEF Efficient Industrial Boilers Project is programmatically and thematically linked to the Chongqing Industrial Pollution Control and Reform Project, which seeks to: (a) significantly reduce industrial pollution from Chongqing's most polluting industry, iron and steel; (b) establish a strategy for reducing industrial pollution for the entire industrial sector; and (c) initiate a pilot program to assist other industrial subsectors to restructure productive facilities, minimize pollution, and adopt modern corporate structures. A loan of $170 million was approved by the Bank's Board of Directors on June 18, 1996.

18. In Chongqing, small and medium-sized industrial boilers account for as much as half of the municipality's coal consumption, contributing to severe air pollution and ambient concentrations of SO_2 which are among the highest in the world. Through the Chongqing Project, Chongqing Municipality is providing support for the implementation of this project, by improving its regulatory structure for controlling boiler emissions, and as a condition of loan effectiveness for the Chongqing project, the municipal government would adopt a plan for reducing boiler SO_2 emissions through implementing a municipal-wide SO_2 pollution levy system. Reduction of non-SO_2 boiler emissions will be addressed through strengthening enforcement of environmental standards for other pollutants. In a parallel effort supported by this project, Chongqing will participate in a pilot program for (a) improving further regulatory enforcement for controlling emissions, and (b) disseminating more efficient and cleaner industrial boiler technologies (see para. 10(c)(iii) and Annex 13).

Project Costs and Financing

19. Preliminary investment cost estimates for the Efficient Industrial Boilers Project are $101.4 million, of which an estimated $68.6 million equivalent would be provided through local counterpart funding, consisting primarily of enterprises' own funds and commercial bank loans. The remaining balance of $32.8 million (SDR 22.8 million) has been approved by the GEF Council to finance the incremental costs involved (see Annex 6). *During negotiations, agreement was reached that the proceeds of the grant will be made available to participating enterprises on terms and conditions satisfactory to the Bank.* Estimated project cost and sources of financing for Phases 1 and 2 are presented in Schedule A and summarized below ($'000):

	Phase 1	Phase 2	Total
Estimated Project Cost:			
(a) Upgrading of existing boilers	15,220	27,846	43,066
(b) Adoption of new boiler models	14,137	21,860	35,997
(c) Technical assistance	1,249	834	2,083
(d) M&E and project management	1,336	783	2,119
(e) Interest during construction	314	5,272	5,586
(f) Contingencies	5,173	7,353	12,526
Total Project Cost	**37,429**	**63,948**	**101,377**

	GEF	Local Bank Loan	Enterprise Self-financed	Total
Financing Plan:				
(a) Upgrading of existing boilers	16,456	25,648	10,991	53,095
(b) Adoption of new boiler models	13,756	21,226	9,098	44,080
(c) Technical assistance	1,294	789		2,083
(d) M&E and project management	1,306	813		2,119
Total sources of financing	**32,812**	**48,476**	**20,089**	**101,377**

Incremental Costs

20. The GEF will finance the incremental costs of the project, calculated as the difference between the costs of the "GEF alternative" and the costs of the "baseline," the latter being defined as the costs that would otherwise be incurred by China to meet the same level of industrial boiler demand. Incremental costs faced by boiler producers to acquire advanced boiler technologies from abroad include licensing, procurement of engineering services, selected purchase of embodied technology, and their commercial demonstration. Additional costs include the modification of production facilities to produce new more energy-efficient boilers. The net incremental cost for boiler producers for undertaking the GEF alternative is approximately $30.2 million. Additional costs of $2.6 million are needed to ensure sustainability and effective implementation of the project, including monitoring and evaluation, and project management. Details of the incremental costs calculations are provided in Annex 6.

Procurement Arrangements

21. Procurement for this project involves the identification of appropriate international suppliers of advanced IB technologies, and the subsequent acquisition of foreign technology and production equipment by the DBMs through licensing and other purchase arrangements. The identification of foreign technology sources is being conducted under an open and competitive process with the objective of acquiring the best available IB technologies for the DBMs at the lowest possible cost. Procurement of

advanced IB technologies from international suppliers for producing the model unit will take place during Phase 1 of the project, followed by procurement of production equipment for mass producing the improved boilers during Phase 2. A summary of the procurement process is discussed below, with additional details provided in Annex 3.

22. **Prequalification of Technology Suppliers.** A notice requesting interested technology suppliers to submit prequalification information and expressions of interest was published in *Development Business* on December 31, 1994 and the *China Mechanical and Electrical Daily* in December 1994. Notification letters were also sent to foreign embassies in Beijing and to trade associations in various countries, and were followed up with telephone inquiries and visits to well-known international boiler and ancillary companies. Based on criteria agreed between PMO and the Bank, 17 international technology suppliers were prequalified. Procedures for selection of technology suppliers are in accordance with the Bank's Procurement Guidelines. The evaluation system for bids incorporates in addition to price, weights for other factors that influence the success of the technology transfer, including adaptability to the Chinese context, service contracts, and personnel training arrangements. Following bid evaluation, an evaluation report along with a revised subproject implementation plan, including revised total project costs, financing plan and timetable of investments, would be sent to the Bank, for a "no objection" response. *During negotiations, agreement was reached that expenditures be made under Phase 1 only for subprojects for which satisfactory implementation plans had been approved by the Bank. PMO will be required to provide the locations of the model units and would assure that environmental assessments from appropriate local government agencies be obtained prior to model unit construction.*

23. **Technology Transfer Phase 1.** During Phase 1, procurement of technology rights and demonstration units will be subject to a two stage bidding process for all subprojects that have two or more prequalified technology sources (Schedule B). Procurement procedures will be based on the Instructions to Bidders from the Bank's Standard Bidding Documents for Supply and the Installation of Plant & Equipment, and the Conditions Of Contract For Process Technology Procurement that have been agreed to by the Bank and Chinese government authorities. For subprojects with only one prequalified technology source, direct contracting will be used for procurement, based on the Bank's Standard Bidding Documents for Supply and the Installation of Plant & Equipment, and the Conditions Of Contract For Process Technology Procurement. Technology rights, goods and services will be procured during Phase 1 through limited international bidding (LIB) estimated to amount to $16.4 million. With the Bank's prior agreement, proprietary items are to be procured through direct contracting, estimated at $6.5 million. Aggregate amounts for LIB and direct contracting cannot be determined at this stage of the technology transfer.

24. At the end of Phase 1 of each subproject, PMO will evaluate the demonstration model and determine whether the model and the participating enterprises have: (a) met predetermined technical and environmental performance criteria; (b) met domestic and

international safety standards; (c) presented an acceptable Phase 2 (i) production plan, including financing; and (ii) marketing plan. Should an enterprise fail to satisfactorily complete the Phase 1 evaluation, MMI would select an alternative subproject, satisfactory to the World Bank. *During negotiations, assurances were received that the verification of the technical and environmental performance of demonstration models for each subproject be carried out according to criteria satisfactory to the Bank, including compliance with domestic and international safety standards, and that expenditures be made under Phase 2 only for subprojects whose model units have met Phase 1 criteria.*

25. **Technology Transfer Phase 2.** During Phase 2, the boiler enterprises that have successfully met their subproject performance criteria will procure production equipment to put the new boiler designs into production. Goods and services procured under shopping are expected to amount to $3.7 million. Items costing more than $250,000, but less than $2 million, are to be procured through international shopping based on quotations from at least three suppliers from at least two countries, up to an aggregate amount not to exceed $2,690,000. Items costing less than $250,000 are to be procured through national shopping, up to an aggregate amount not to exceed $1,000,000. Bank-approved proprietary items, procured through direct contracting, are expected to amount to $3.9 million.

26. Consultants for both Phases will be engaged on the basis of Guidelines for the use of Consultants by World Bank Borrowers and World Bank as Executing Agency dated August, 1981. Prior review of about 80 percent of procurement documentation by the Bank will include all goods contracts of $200,000 equivalent or more, and all consultant services in excess of $100,000 equivalent for firms, and above $50,000 equivalent for individuals. For contracts not subject to prior review, post review will be carried out during project supervision, to include at least 25 percent of such contracts. The consultant terms of reference and technical requirements regarding experience and capacity, single selection of consulting firms, and amended contracts which exceed their thresholds, will be subject to prior review for all consultancy contracts.

Project Implementation

27. MMI is responsible for the overall implementation of the project. A Project Leading Group (PLG) was established at project inception with the Vice-Minister of MMI as head of the PLG. A PMO was organized under the PLG to oversee project preparation and coordination of various project implementation activities. During project preparation, PMO established capable technical support and administrative teams to carry out project implementation. Following additional training in Bank procedures and guidelines, the administrative team will be responsible for procurement, disbursement, and financial aspects of the project during implementation. PMO has also appointed two companies under MMI to assist in carrying out implementation activities: (i) the China Machine-Building International Corporation (CMIC) will be responsible for procurement of goods and services for all subprojects; and (ii) the Beijing Clean Combustion Engineering Co. Ltd. (BCCEC) will be responsible for procurement of the rights to the

advanced technology, and will assist with industry-wide issues related to technology diffusion of high-efficiency and cleaner industrial boilers, product standardization, and quality control. *During negotiations, assurances were received that PMO be maintained with sufficient competent staff on a full- or part-time basis, as required, to carry out the project, including: (a) boiler house design engineer to analyze and evaluate boiler house design and ensure compliance with design and safety standards; (b) boiler design and manufacturing engineer to analyze and evaluate boiler and other production facility designs and provide quality control assurance and monitoring; (c) boiler test engineer to provide field testing and evaluation of boilers; (d) environmental engineer to work with enterprises to ensure that boiler house designs are consistent with the project environmental objectives; (e) lawyer/legal expert to provide advice on legal aspects of technology transfer and assist in subproject contractual negotiations; (f) accountant/disbursement expert familiar with Bank disbursement procedures to handle disbursement, accounting and internal auditing; (g) financial analyst familiar with Bank reporting requirements to monitor the financial condition and performance of the participating enterprises and subprojects, and prepare periodic reports for the Recipient and the Bank; (h) procurement expert familiar with Bank procurement procedures to prepare procurement packages and bidding documents; (i) marketing/commercial expert with boiler sector experience to help develop enterprise commercial strategies and marketing plans and plans for dissemination of the new boiler technologies; and (j) training coordinator to plan, coordinate and implement training at the enterprise and municipal levels.* The services of such staff would be obtained prior to December 31, 1996. PMO will also obtain support from the National Environment Protection Agency (NEPA) for conducting environmental evaluations during the verification of boiler demonstration models, monitoring emissions indicators of the boilers, reviewing and formulating new standards and emissions fee systems, and help in the establishment of local pilot programs for effective dissemination of the new boiler technologies.

28. With Bank assistance, PMO has prepared a PIP (see Project File) and a summary of key events in the Project Implementation Schedule (Annex 4). The proposed project would be implemented over a four-year period from 1997-2000. A Grant Agreement between the World Bank and the Chinese Government represented by the Ministry of Finance (MOF) establishes the terms and conditions of project implementation. To ensure that the nine subprojects are implemented smoothly, there will be a Subgrant Agreement, satisfactory to the Bank, for each of the nine subprojects to be signed by the participating DBMs and MMI. *During negotiations, agreement was reached that: (a) each subgrant shall not exceed 40 percent of any boiler subproject cost, net of taxes; (b) at least 10 percent of the total cost of any boiler subproject shall be financed by the enterprise concerned from resources raised on its own; and (c) at least 25 percent of the proceeds of any subgrant shall be allocated to Phase 2 of the project.*

29. Project grant funds will be channeled through a Special Account to be set up by MOF. MOF will reimburse all expenditures incurred by the enterprises upon approval and verification by PMO. Estimated disbursements are presented in Schedule C.

Disbursement would be 100 percent for subgrants for foreign technology acquisition, including proprietary equipment and training. Disbursement for goods for project management will follow the World Bank's standard disbursement guidelines of 100 percent of foreign expenditures, 100 percent of local ex-factory expenditures, and 75 percent of local expenditures for other items procured locally.

Monitoring and Evaluation

30. Monitoring of project implementation will be the responsibility of PMO. BCCEC will assist with the monitoring and evaluation of implementation activities and performance indicators. Implementation activities will be monitored by tracking essential inputs to the project, including the amount of GEF grant funds received, the progress of disbursement, the availability of counterpart financing, technology transfer contracts signed, consultants hired, and equipment purchased, according to the two phases of project implementation described in the PIP. Reporting of these activities will form part of PMO's semiannual project implementation progress report. Two sets of implementation performance indicators will be monitored: (a) *output/outcome indicators* will be used to track the thermal efficiency of the model boilers units, and a final evaluation of the model units will be undertaken at the completion of Phase 1 (1998/1999); and (b) *development impact indicators* will measure the success of the project as they relate to its environmental objectives. The nature of this project is such that impact of the reduction of CO_2 emissions from improved coal use will be measured only two years after the project is completed (2002), because the reduction in the interim years will be minimal. Participating boiler manufacturers are therefore being required to keep track of the thermal efficiency of all the boilers that they produce and sell, including the model unit, starting in Phase 2 when mass production is initiated, until 2002. Specifically, as part of their subproject completion report, they should include information on the amount of coal use per steam-ton of output from a sample of new boilers that they produced and sold during the project implementation period. *During negotiations, assurances were received that PMO would monitor and evaluate the progress of the project in accordance with indicators agreeable to the Bank.* The output/outcome and development impact indicators are summarized below; the indicators, as well as additional details, will be included in a supplemental letter to the Grant Agreement, and are provided in Annex 7. The Bank's project supervision plan is shown in Annex 11.

(a) Output/outcome indicators (1999/2000):

- Higher thermal efficiencies in model boiler units
- Reduced dust emissions in model boiler units
- Reduced SO_2 emissions in model boiler units

(b) Development impact indicators:

- Reduced CO_2 emissions through improved coal utilization: to be monitored two years after project completion (2002).

- Increased new boiler production and sales volume of each subproject:

    - 18,000 tph at project completion (2000)
    - 27,000 tph two years after project completion (2002)

- Ratio of new boilers to total boiler production:

    - 19,000/100,000 tph at project completion (2000) = 19 percent
    - 36,820/105,000 tph two years after project completion (2002) = 35 percent

Reporting and Auditing

31. PMO would be responsible for the preparation of semiannual reports on progress of project implementation, disbursement status of each subproject, and annual reports on the financial status of each subproject enterprise and monitoring and evaluation of the project. Auditing of the proposed project will be conducted by the State Audit Administration's Foreign Funds Application Department. *During negotiations, assurances were received that the following reports would be submitted to the Bank: (a) annual audits, within six months of the end of the financial year: (i) audit of project accounts maintained by PMO; (ii) audit of the Special Account; and (iii) audit of statements of expenditures (SOEs); (b) annual reports on the financial condition and operational status of each subproject enterprise, no later than February 15 of each year, according to parameters agreed with the Bank; and (c) semiannual progress reports on progress achieved in carrying out the project, and the disbursement status of each subproject, not later than February 15 and August 15 of each year.*

Project Sustainability

32. Sustainability of the project will depend on the technical strengths and financial advantages of the new boiler models being introduced, and on the successful marketing and dissemination of the boilers by Chinese boiler manufacturers, industry associations, MMI, and local energy and environmental agencies. Major stakeholders in the project (boiler producers, users, research institutes, government agencies, international agencies) have been involved in the design and preparation of the project, and will be included in implementation. Leading and well-established DBMs with sound financial positions have been selected to participate in the project through an open and competitive process. Assistance is being provided to DBMs in product marketing and customer service. Prior to going ahead with the mass production of the new models, DBMs will have to provide the Bank with satisfactory marketing and financing plans. Technologies that are proven to be technically and commercially successful will be disseminated to other boiler

producers in China. Design and research institutes will be involved in extending the improved international designs into other boiler models, and in improving the standards for boiler auxiliary equipment. A pilot program involving national and local environment and planning agencies will be established in Beijing, Chongqing and Harbin for the purpose of stimulating the demand for more efficient and cleaner industrial boilers. The intent of the municipal pilot programs is to provide information to boiler consumers on the benefits of adopting the new boilers, and developing penalties for the continued use of older inefficient boilers through stricter enforcement of environmental emissions standards. *During negotiations, assurances were received that a plan for the implementation of the pilot dissemination in each of the municipalities participating in the program will be submitted to the Bank no later than February 28, 1997.*

Bank Group Assistance Strategy and the Rationale for Bank and GEF Involvement

33. China ratified the United Nations Framework Convention on Climate Change on January 5, 1993. The project is consistent with Operational Program #5 of the GEF Operational Strategy for climate change, where one of the long-term mitigation measures is to remove the barriers to energy conservation. The Bank Group's assistance to China emphasizes environmental protection as articulated in the Country Assistance Strategy (CAS) presented to the Board on June 1, 1995 and the Progress Report discussed on March 26, 1996. The CAS calls for working with the GEF to reduce GHG emissions, among other objectives. The Bank's environmental strategy for the industrial sector seeks to reduce industrial point source pollution within the context of improvements in the regulatory incentive structure and reform of the industrial enterprises involved. Bank sector work underpins and validates this approach. *China: Environmental Strategy Paper* (1992) highlights the interrelationships between environmental issues and economic growth issues, such as technology development and transfer. *China: Efficiency and Environmental Impacts of Coal Use* (1991) identifies various means of reducing China's serious SO_2 and TSP problems by using coal more efficiently, especially through technology transfer and improving the operating efficiency and technical quality of conventional industrial boilers. Finally, the *China Greenhouse Gas Study* (1994) and the 1994 prefeasibility study for boilers mentioned above, note the key role of economic reforms in controlling GHG and other forms of pollution, the need for a parallel strengthening of the environmental regulatory system, and the importance of technology transfer for achieving effective energy efficiency and pollution control.

Lessons Learned

34. As China moves from a planned to a market economy, it is important to design projects that emphasize market solutions. The Bank's experience in industrial lending has revealed the importance of early involvement of the enterprises which will have to operate in such markets. The GEF Efficient Industrial Boilers Project is innovative in this regard in that proposals on measures to increase thermal efficiency of industrial boilers were solicited from domestic boiler enterprises. Domestic firms were provided information about foreign advances in boiler design and production, including the

opportunity to visit international technology suppliers. The final selection of both domestic and foreign participating firms is being done through an open and competitive process. The Bank's experience in dealing with the public sector in China has also shown that it is critical to involve government agencies at both the central and local government levels. MMI is responsible for implementing the project but will work closely with provincial and municipal governments in the dissemination of the new boiler technology.

35. The GEF Efficient Industrial Boilers Project is the first project in a series of GEF and Bank operations in China designed to improve the efficiency of energy use and to promote the use of renewable energy. In undertaking a new initiative, it is critical to identify and obtain the commitment of major stakeholders (see Annex 8). An extended dialogue during the prefeasibility study and preparation of the GEF project has resulted in a strong commitment from the Chinese government to this project. Input on project design has also been sought from a broad range of stakeholders in the boiler industry at large, and among the municipalities which will be the long term beneficiaries of this project.

36. Lessons learned from designing industrial projects, which can reduce risk and contribute to successful implementation, have been applied to this project. They include: (a) utilizing market studies to provide clear cost-benefit tradeoffs to introducing and disseminating new technologies; (b) the phasing of disbursement to make sure that the phase two financing of mass production of new boiler prototypes only takes place after phase one model verification is satisfactorily concluded; (c) strengthening regulatory enforcement governing boiler operations in parallel with the adoption of the new technology; and (d) ensuring sufficient local counterpart financing is available, including commitments from lenders and beneficiary enterprises to provide their own resources.

Environmental Aspects

37. The industrial boiler sector currently accounts for about 28 percent of China's CO_2 emissions, 37 percent of TSP emissions, and 39 percent of SO_2 emissions from energy consumption. As shown in the project benefits section (para. 40), the project will result in significant reductions of GHG emissions, which will reduce the threat of global climate change. In addition, particulate and sulfur emissions will be reduced through reduced coal consumption, coal preparation, the use of advanced cyclones and baghouses, and the adoption of sulfur-control combustion technology (FBC) in boiler design. In accordance with the requirements of OD 4.01 (Environmental Assessment—EA), the project has been assigned an environmental category of "B", and an environmental analysis report satisfactory to the Bank has been prepared. As with all industrial boiler installations in China, local environmental clearance will be needed prior to construction of the nine subproject model boiler units. The pollution control improvements embodied in the new boiler technologies will be disseminated throughout China's boiler industry, and will be the basis for reviewing existing environmental standards for industrial boilers and making recommendations for revising such standards (see Annex 13).

Economic and Financial Analysis

38. The improvement of domestic boiler design and production capabilities through technology transfer was determined to be one of the most cost-effective and immediately implementable of the options for improving energy efficiency in the industrial boiler sector. Without the project, it has been estimated that there would be unnecessary energy use on the order of 300-500 million tons of coal over the life of the project, and excess emissions of 600-1,000 million tons of CO_2. In addition to the reduction in CO_2, the project will generate substantial financial benefits to consumers in terms of lower energy expenditures and significant, though less easily quantifiable, benefits in terms of reduced TSP and SO_2 emissions.

39. Market prices of the new boilers were estimated based on price surveys of existing boiler models and on the cost projections for new boilers carried out in the project financial and economic analysis. (See Annex 5) The new boiler prices were between 14 and 20 percent higher than existing (less efficient) comparably-sized boiler models. Rate of return analysis for both consumers and producers was undertaken using market prices for coal and the estimated market prices of the new boilers. The incremental analysis ("with" minus "without" project case) for consumers was found to generate internal rate of returns (IRRs) of between 20 and 30 percent, depending on the subproject, and payback periods of four to five years, similar to existing boiler models. Without the GEF grant, the prices of the new boilers were found to be between 25 and 35 percent higher than existing (less efficient) comparably-sized models, resulting in lower IRRs and longer payback periods for consumers than for existing boilers. The incremental analysis for producers found that the IRR was between six and seven percent without the GEF grant, and 11 to 13 percent with the GEF grant. The economic and financial analysis (Annex 5) shows that the IRRs for both boiler producers and consumers are very sensitive to changes in the price of the new boiler. While increases in the boiler price will have large positive benefits for boiler producers, price decreases, which are unlikely, would pose serious financial difficulties for boiler producers. Once the new boilers have been proven in the market, and the nonfinancial benefits of the boilers displayed, consumers are likely to accept a higher price for the new boilers. Details on economic analysis and industrial boiler market survey can be found in Annexes 5 and 10, respectively.

Project Benefits and Risks

40. Upgrading the technology of Chinese coal-fired industrial boilers is a critical element in China's plan to increase the overall energy efficiency of the economy, and in the process, reduce both local (TSP, SO_2) and global (CO_2) emissions through reduced fuel use. The more efficient industrial boilers developed under the project are projected to account for roughly 35 percent of IB output by the year 2002, and should grow to 50-60 percent of total IB output in China by the year 2010. **Direct** coal savings of IB boilers produced by the participating DBMs are estimated at about 102 million tons (Mt) of coal, resulting in the reduction of about 181 Mt of CO_2. **Indirect** benefits of the project,

through the dissemination of advanced boiler designs and auxiliary equipment to other boiler producers, are conservatively estimated to be in the range of 230-416 Mt of coal savings, and a reduction of CO_2 of 456-824 Mt. The net cost per ton of CO_2 reduced for the GEF investment for the project is between $0.03 and $0.05 per ton of CO_2 (total **direct** plus **indirect** CO_2 reductions), which is substantially below $20 per ton that has been proposed by some developed countries as a shadow value for CO_2. Improved boiler designs will also result in significant reductions of local pollution emissions, especially TSP and SO_2, which has been shown to have important benefits to human health. **Direct** project reductions alone of TSP and SO_2 are estimated at 4.5 and 25.4 million tons, respectively, through both energy efficiency improvements and the introduction of emission control technologies.

41. Additional important benefits to China are the safety, reliability, and additional environmental benefits embodied in advanced boiler technologies from abroad. The project will address the two other major factors responsible for the relatively low operational thermal efficiency achieved by Chinese industrial boilers, namely, efficient boiler operation, and inconsistent and poor quality coal supply. Through technical assistance components (see Annex 13), the project will strengthen efficiency, safety, and environmental standards for industrial boilers, establish a training program for boiler operators, and identify the benefits of, and regulatory measures needed to improve, the quality of coal supplied to industrial boilers.

42. The project is subject to technical, commercial, and financial risks. Technical risks are viewed as limited, in that all of the boiler designs proposed have been commercially demonstrated abroad. One serious technical risk is the inability of the new boilers to achieve target operational thermal efficiencies due to poor operation. This risk is being reduced through the establishment of a boiler operator training and certification program under the project. Technical risk is also being minimized through competitive bidding for DBMs, close collaboration between Chinese and international engineers, and the evaluation of technical performance of the model units at the end of Phase 1, and with successful evaluation as a condition of Phase 2. Commercial risk will be reduced by requiring DBMs to have a clear marketing strategy in place, prior to moving to Phase 2 mass production. The use of the GEF grant to purchase foreign technology licenses will help to ensure the successful marketing of the boilers by limiting the financial cost of technology transfer, and thus limiting the price increase of the new boiler (see para. 39 and Annex 5). Market price surveys and project economic analysis show that it will be difficult for the new boilers to be marketed if the price increases for the nine new boilers is more than 15-20 percent higher than existing comparable models. The price of the new boilers used in the analysis takes into consideration a pricing level sufficient to induce boiler users to switch to the new boilers while at the same time minimizing the subsidy from the grant. This calibration of the pricing level to accommodate both objectives is inherently risky as noted in the sales price analysis in Annex 5 (para. 8). Commercial and financial risks will also be reduced by: (a) requiring that DBMs have the required counterpart funding (including a commitment letter from a bank) as part of their feasibility study, and a clear and verifiable financing plan prior to going into commercial

production; and (b) working with local governments to establish a pilot program for marketing the energy-efficient and less-polluting boilers by strengthening enforcement of boiler emission regulations, beginning in municipalities where industrial boilers have been identified as serious sources of pollution.

Agreements Reached

43. During negotiations, agreement was reached with the Recipient:

(a) that the proceeds of the grant would be made available to participating enterprises on terms and conditions satisfactory to the Bank (para. 19);

(b) to require that the locations of the model units be identified and that environmental assessments from appropriate local government agencies be obtained prior to model unit construction (para. 22);

(c) to carry out the verification of the technical and environmental performance of model units for each subproject according to criteria satisfactory to the Bank, and to test compliance with domestic and international safety standards (para. 24);

(d) to maintain PMO with sufficient competent staff to carry out the project (para. 27);

(e) to ensure that each subgrant shall not exceed 40 percent of any boiler subproject cost, net of taxes (para. 28);

(f) to ensure that at least 10 percent of the total cost of any boiler subproject shall be financed by the participating enterprise concerned from resources raised on its own (para. 28);

(g) to ensure that at least 25 percent of the proceeds of any subgrant shall be allocated to Phase 2 of the subproject (para. 28);

(h) to monitor and evaluate the progress of the project in accordance with indicators satisfactory to the Bank (such indicators are included in a supplemental letter to the Grant Agreement) (para. 30);

(i) to furnish the Bank with independently audited financial statements for the Special Account, statements of expenditure, project accounts and relevant records, within six months of the end of each fiscal year (para. 31);

(j) to submit semiannual progress reports on progress achieved in carrying out the project, and the disbursement status of each subproject, not later than February 15 and August 15 of each year (para. 31);

(k) to submit annual reports by February 15 on the financial condition and operational status of each subproject enterprise according to parameters agreed with the Bank (para. 31);

(l) to prepare and furnish to the Bank no later than February 28, 1997 a plan for the implementation of the pilot dissemination in each of the municipalities participating in the program (para. 32).

44. As a condition of disbursement, the Recipient would:

(a) ensure that expenditures under Phase 1 are incurred only for subprojects whose subgrant agreement has been approved by the Bank, and which have a satisfactory implementation plan (para. 22); and

(b) ensure that expenditures under Phase 2 are incurred only for subprojects which have met evaluation criteria satisfactory to the Bank (para. 24).

SCHEDULE A: COST ESTIMATES AND FINANCING PLAN
($'000)

Estimated Costs	First Phase			Second Phase			
	Local	Foreign	Subtotal	Local	Foreign	Subtotal	Total
Upgrading of Existing Boilers:							
Construction Engineering	-	-	-	3,069	-	3,069	3,609
Equipment	4,626	1,311	5,937	4,755	3,933	8,688	14,625
Technology Transfer Licensing	-	9,075	9,075	-	-	-	9,075
Engineering Services	-	5,595	5,595	-	-	-	5,595
License	-	3,480	3,480	-	-	-	3,480
Installation	-		-	-	-	-	-
Others	-	-	-	796	-	796	796
Working Capital	208	-	208	14,753	-	14,753	14,961
Subtotal	**4,834**	**10,386**	**15,220**	**23,913**	**3,933**	**27,846**	**43,066**
Adoption of New Boiler Design:							
Construction Engineering	-	-	-	2,544	-	2,544	2,544
Equipment	3,973	1,160	5,133	4,167	2,520	6,687	11,820
Technology Transfer Licensing	-	8,310	8,310	-	-	-	8,310
Engineering Services	-	4,872	4,872	-	-	-	4,872
License	-	3,438	3,438	-	-	-	3,438
Installation	-	-	-	347		347	347
Others	-	-	-	-	-	-	-
Working Capital	694	-	694	12,282	-	12,282	13,522
Subtotal	**4,667**	**9,470**	**14,137**	**19,340**	**2,520**	**21,860**	**35,997**
Technical Assistance	424	825	1,249	365	469	834	2,083
Project Monitoring & Evaluation	151	610	761	353	195	548	1,309
Project Management	205	370	575	104	131	235	810
Subtotal	**780**	**1,805**	**2,585**	**822**	**795**	**1,617**	**4,201**
Total	**10,281**	**21,661**	**31,992**	**44,075**	**7,248**	**51,323**	**83,265**
Physical Contingencies	860	1,986	2,846	1,622	645	2,267	5,113
Price Contingencies	1,494	833	2,327	4,647	439	5,086	7,413
Total Project Cost	**12,635**	**24,480**	**37,115**	**50,344**	**8,332**	**58,676**	**95,791**
Interest During Construction	314	-	314	5,272	-	5,272	5,586
Total Financing Required	**12,949**	**24,480**	**37,429**	**55,616**	**8,332**	**63,948**	**101,377**
Sources of Financing							
GEF	-	24,480	24,480	-	8,332	8,332	32,812
Local Bank Loan	8,252	-	8,252	19,676	-	19,676	27,928
Working Capital Loan	632	-	632	18,925	-	18,925	19,557
Enterprise Self-raised Fund	4,065	-	4,065	17,015	-	17,015	21,080
Total Sources of Financing	**12,949**	**24,480**	**37,429**	**55,616**	**8,332**	**63,948**	**101,377**

SCHEDULE B: PROCUREMENT ARRANGEMENTS
($'000)

Project Components	LIB	Direct Contract	Others /a	Total
Phase 1				
Upgrading of existing boilers	6,861	5,081	-	11,942
Adoption of new boiler designs	9,550	1,370	-	10,920
Phase 1 Subtotal	**16,411**	**6,451**		**22,862**
Phase 2				
Production Equipment	-	3,910	3,440	7,350
Technical Assistance (TA)				
1. Operator Training	-	-	234	234
2. Marketing/dissemination	-	-	350	350
3. Revision of standards	-	-	350	350
4. Boiler Design and Implementation	-	-	185	185
5. Boiler house standards development	-	-	175	175
Subtotal	-	-	**1,294**	**1,294**
Monitoring and Evaluation (M&E)				
1. Project evaluation	-	-	122	122
2. Thermal efficiency monitoring	-	-	127	127
3. Emissions monitoring	-	-	157	157
4. Safety validation	-	-	200	200
Subtotal	-	-	**606**	**606**
Project Management (PM)	-	-	450	450
Office and Monitoring & Evaluation Equipment	-	-	250	250
Total TA/M&E/PM	-	-	**2,600**	**2,600**
Total GEF financing	**16,411**	**10,361**	**6,040**	**32,812**

/a: Others include international and national shopping, and consultant services.

SCHEDULE C: ESTIMATED DISBURSEMENT SCHEDULE

Category	Grant Amount ($ million)	Percentage of Financing
1. Subgrants	26.309	100%
2. Consultant Services	2.350	100%
3. Goods (for project management)	0.250	100% of foreign expenditures 100% of local expenditures (ex-factory cost) 75% of local expenditures for other items procured locally
4. Unallocated	3.903	
Total	**32.812**	

ESTIMATED DISBURSEMENT

IBRD Fiscal Year	1998	1999	2000	2001
Annual	17.4	13.0	2.2	0.2
Cumulative	17.4	30.4	32.6	32.8

SCHEDULE D: TIMETABLE OF KEY PROJECT PROCESSING EVENTS

	Key Dates
1. Identification Mission	Jan 1994
2. Preparation Mission	Jul 1-15, 1994
3. Project Preparation Advance approved by GEF Operations Committee	Mar 15, 1995
4. Preappraisal Mission	Dec 10-22, 1995
5. GEF Council Endorsement	Apr 4, 1996
6. Final Executive Project Summary (FEPS) Review Meeting	Jun 12, 1996
7. Appraisal Mission	Jun 30, 1996
8. Prenegotiation package to RVP and AGCO	Sep 25, 1996
9. AGCO and RVP Clearance and initiate Invitation to Negotiate	Oct 2, 1996
10. Send formal invitation to negotiate to borrower	Oct 10, 1996
11. Submit the revised version of Project Document to GEF Council	Oct 10, 1996
12. Negotiation in Washington	Nov 11-15, 1996
13. Clearance from Director	Nov 22, 1996
14. Receive letter from GEF CEO clearing the project for final approval	Nov 22, 1996
15. Send approved final package with Cover Form (2337/BP 10.00 Annex I) to the Board	Dec 4, 1996
16. Board Presentation	Dec 23, 1996
17. Planned Effectiveness Date for the Grant	Dec 31, 1996
18. Planned Project Completion	Dec 31, 2000
19. Planned Project Closing Date	Jun 30, 2001

Schedule E
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STATUS OF BANK GROUP OPERATIONS IN THE PEOPLE'S REPUBLIC OF CHINA
A. STATEMENT OF BANK LOANS AND IDA CREDITS
(As of September 30, 1996)

Loan/ Credit Number	FY	Borrower	Purpose	Amount (US$ million) (net of cancellations) Bank	IDA	Undisb.(a)
		47 loans and 51 credits have been disbursed		4,596.8	3,432.2	-
		of which SECAL:				
2967/1932	88	PRC	Rural Sector Adj.	200.0	93.2	-
Active Loans						
1885	88	PRC	Northern Irrigation	-	103.0	1.4
2951/1917	88	PRC	Sichuan Highway	75.0	(50.0)(b)	0.8
2968	88	PRC	Railway IV	200.0	-	2.8
1997	89	PRC	Shaanxi Prov. Agriculture	-	106.0	0.2
2009	89	PRC	Integrated Reg. Health	-	52.0	1.2
3022	89	PRC	Tianjin Light Industry	154.0	-	5.6
3060/2014	89	PRC	Inner Mongolia Railway	70.0	(80.0)(b)	0.8
3066	89	PRC	Hubei Phosphate	137.0	-	3.3
3073/2025	89	PRC	Shandong Prov. Highway	60.0	(50.0)(b)	15.1
2114	90	PRC	Vocational & Tech. Educ.	-	50.0	1.7
2145	90	PRC	National Afforestation	-	300.0	12.3
2159	90	PRC	Hebei Agricultural Dev.	-	150.0	5.3
2172	91	PRC	Mid-Yangtze Agricultural Dev.	-	64.0	1.6
3265/2182	91	PRC	Rural Credit IV	75.0	200.0	1.4
3274/2186	91	PRC	Rural Indust Tech (SPARK)	50.0	64.3	4.4
3286/2201	91	PRC	Medium-Sized Cities Dev.	79.4	89.0	6.0
2210	91	PRC	Key Studies Development	-	131.2	10.8
2219	91	PRC	Liaoning Urban Infrastructure	-	77.8	4.8
2242	91	PRC	Henan Agricul. Dev.	-	110.0	15.0
3337/2256	91	PRC	Irrig. Agricul. Intensif.	147.1	187.9	15.4
3387	92	PRC	Ertan Hydroelectric	380.0	-	2.9
2294	92	PRC	Tarim Basin	-	125.0	12.2
2296	92	PRC	Shanghai Metro Transport	-	60.0	8.2
3406	92	PRC	Railways V	330.0	-	38.3
3412/2305	92	PRC	Daguangba Multipurpose	30.0	37.0	4.6
2307	92	PRC	Guangdong ADP	-	162.0	75.6
3415/2312	92	PRC	Beijing Environment	45.0	80.0	43.7
2317	92	PRC	Infectious and Endemic Disease Cont.	-	129.6	74.9
3433	92	PRC	Yanshi Thermal Power	180.0	-	7.5
2336	92	PRC	Rural Water Supply and Sanitation	-	110.0	27.7
2339	92	PRC	Educ. Development in Poor Provs.	-	130.0	24.0
3443	92	PRC	Regional Cement Industry	82.7	-	12.3
3462	92	PRC	Zouxian Thermal Power	310.0	-	37.8
3471	92	PRC	Zhejiang Provincial Highway	220.0	-	84.0
2387	92	PRC	Tianjin Urban Devt. & Envir.	-	100.0	50.4
2391	92	PRC	Ship Waste Disposal	-	15.0	10.6
2411	93	PRC	Sichuan Agricultural Devt.	-	147.0	50.5
3515	93	PRC	Shuikou Hydroelectric II	100.0	-	47.4
2423	93	PRC	Financial Sector TA	-	60.0	47.0
3530	93	PRC	Guangdong Provincial Transport	240.0	-	57.1
3531	93	PRC	Henan Provincial Transport	120.0	-	33.0
2447	93	PRC	Ref. Inst'l and Preinvest.	-	50.0	29.4
3552	93	PRC	Shanghai Port Rest. and Devt.	124.3	-	15.1
2457	93	PRC	Changchun Water Supply & Env.	-	120.0	82.7
2462	93	PRC	Agriculture Support Services	-	115.0	29.4
3560/2463	93	PRC	Taihu Basin Flood Control	100.0	100.0	107.6
2471	93	PRC	Effective Teaching Services	-	100.0	57.2
3572	93	PRC	Tianjin Industry II	134.0	-	110.0
3581	93	PRC	Railway VI	420.0	-	215.1
3582	93	PRC	South Jiangsu Envir. Prot.	250.0	-	71.5
2475	93	PRC	Zhejiang Multicities Devt.	-	110.0	81.3
3606	93	PRC	Tianhuangping Hydroelectric	300.0	-	232.4
3624/2518	93	PRC	Grain Distribution	325.0	165.0	456.2
2522	93	PRC	Environmental Tech. Assist.	-	50.0	30.4
2539	94	PRC	Rural Health Workers Devt.	-	110.0	76.9
3652	94	PRC	Shanghai Metro Transport II	150.0	-	20.0
3681	94	PRC	Fujian Provincial Highways	140.0	-	98.1
3687	94	PRC	Telecommunications	250.0	-	179.4
2563	94	PRC	Second Red Soils Area Devt.	-	150.0	72.4
2571	94	PRC	Songliao Plain Agric. Devt.	-	205.0	113.7
3711	94	PRC	Shanghai Environment	160.0	-	134.2
3716	94	PRC	Sichuan Gas Devt & Conservatn.	255.0	-	182.3

STATUS OF BANK GROUP OPERATIONS IN THE PEOPLE'S REPUBLIC OF CHINA
A. STATEMENT OF BANK LOANS AND IDA CREDITS
(As of September 30, 1996)

Loan/ Credit Number	FY	Borrower	Purpose	Amount (US$ million) (net of cancellations) Bank	IDA	Undisb.(a)
3718	94	PRC	Yangzhou Thermal Power	350.0	-	279.7
B103	94	PRC	Yangzhou Thermal Power	57.2	-	56.7
3727	94	PRC	Xiaolangdi Multipurpose	460.0	-	209.5
2605	94	PRC	Xiaolangdi Resettlement	-	110.0	66.6
2616	94	PRC	Loess Plateau Watershed Devt.	-	150.0	88.7
2623	94	PRC	Forest Resource Devt. & Prot.	-	200.0	152.1
3748	94	PRC	National Highway	380.0	-	234.4
3773/2642	95	PRC	Ent. Housing/Soc Sec Reform	275.0	75.0	314.0
3781	95	PRC	Liaoning Environment	110.0	-	87.4
3787	95	PRC	Xinjiang Prov. Highways	150.0	-	116.4
2651	95	PRC	Basic Ed for Poor/Minorities	-	100.0	65.6
3788	95	PRC	Shenyang Industrial Reform	175.0	-	156.8
2654	95	PRC	Economic Law Reform	-	10.0	8.7
2655	95	PRC	Comp Maternal/Child Health	-	90.0	58.1
3846	95	PRC	Zhejiang Power Development	400.0	-	370.0
B105	95	PRC	Zhejiang Power Development	64.3	-	62.3
3847	95	PRC	Technology Development	200.0	-	195.0
3848	95	PRC	Sichuan Power Transmission	270.0	-	270.0
3873/2709	95	PRC	Fiscal TA	25.0	25.0	45.4
3874/2710	95	PRC	Yangtze Basin Water Res Devt	100.0	110.0	146.6
3897	95	PRC	Railway VII	400.0	-	400.0
3906/2744	95	PRC	Southwest Poverty Reduction	47.5	200.0	215.0
3910	95	PRC	Inland Waterways	210.0	-	203.4
3914/2756	95	PRC	Iodine Deficiency Dis. Control	7.0	20.0	23.2
3929	96	PRC	Shanghai-Zhejiang Highway	260.0	-	219.7
3933	96	PRC	Ertan II Hydroelectric	400.0	-	342.0
B106	96	PRC	Ertan II Hydroelectric	50.0	-	48.6
2794	96	PRC	Disease Prevention	-	100.0	92.7
3966/2799	96	PRC	Hubei Urban Environment (c)	125.0	25.0	150.0
3967/2800	96	PRC	Labor Market Development	10.0	20.0	27.4
3980	96	PRC	Henan (Qinbei) Thermal (c)	440.0	-	440.0
3986	96	PRC	Second Shaanxi Prov. Highways	210.0	-	210.0
3987	96	PRC	Second Shanghai Sewerage	250.0	-	250.0
2831	96	PRC	Third Basic Education	-	100.0	92.7
2834	96	PRC	Shanxi Poverty Alleviation	-	100.0	97.1
4001	96	PRC	Animal Feed	150.0	-	150.0
4027	96	PRC	Second Henan Prov. Highway	210.0	-	210.0
4028/2870	96	PRC	Gansu Hexi Corridor	60.0	90.0	149.2
4044/2886	96	PRC	Seeds Sector Commercialization (c)	80.0	20.0	100.0
4045	96	PRC	Chongqing Ind. Pollution Control (c)	170.0	-	170.0
4055/2892	96	PRC	Yunnan Environment (c)	125.0	25.0	150.0
4063/2898	97	PRC	Vocational Education Reform (c)	10.0	20.0	20.0
			Total	**16,395.8**	**8,914.9**	**10,014.0**
			of which has been repaid	1,559.0	42.8	
			Total now held by Bank and IDA (a)	14,836.8	8,872.1	
			Amount sold: Of which repaid	-	-	
			Total Undisbursed	**7,635.3**	**2,378.7**	**10,014.0**

(a) As credits are denominated in SDRs (since IDA Replenishment VI), undisbursed SDR credit balances are converted to dollars at the current exchange rate between the dollar and the SDR. In some cases, therefore, the undisbursed balance and total credit amount held indicate a dollar amount greater than the original principal credit amount expressed in dollars.

(b) Fully disbursed.

(c) Not yet effective.

B. STATEMENT OF IFC INVESTMENTS
(As of September 30, 1996)

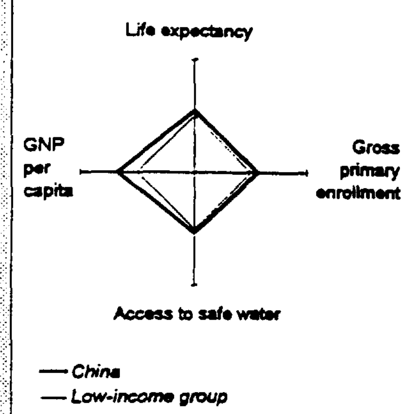
FY	Borrower	Type of Business	Loan	Equity	Syndicate	Total
			---------- (US$ Million) ----------			
85/92	Guangzhou Peugeot Auto	Automobile	2.8	4.6	-	7.4
88/ 92/94	Shenzhen China Bicycles Co. Ltd.	Bicycle Manufacture	8.5	3.4	-	11.9
89	Crown Electronics	Manufacturing	3.9	-	-	3.9
93	Shenzhen Tai-Yang PCCP	Construction Material	3.8	1.0	-	4.8
93	Yantai Mitsubishi Cement	Cement	18.7	2.0	10.0	30.7
94	Dalian Glass	Glass	20.5	2.4	40.5	63.4
94	China Walden Investors	Venture Capital	-	7.5	-	7.5
94	Dynamic Growth Fund	Venture Capital	-	12.4	-	12.4
94	Plantation Timber Product	Timber, Pulp & Paper	10.0	1.0	20.0	31.0
95	Newbridge Investment	Venture Capital	-	10.0	-	10.0
95	Nantong Wanfu (EEI)	Agribusiness	6.3	2.7	-	9.0
95	Dupont Suzhou Polyester	Textiles	24.9	3.8	52.0	80.7
96	Nanjing Kumho Tire Co., Lt	Motor Vehicles	16.0	3.8	45.5	65.3
96	Weihai Weidongri		4.9	-	-	4.9
	Total Gross Commitments					**342.9**
	Total Commitments now Held by IFC					167.1
	Total Undisbursed					**175.8**

Schedule F
Page 1 of 2

China at a glance

POVERTY and SOCIAL	China	East Asia	Low-income
Population mid-1995 *(millions)*	1,201.4	1,709	3,188
GNP per capita 1995 *(US$)*	620	830	460
GNP 1995 *(billions US$)*	744.9	1,418	1,466
Average annual growth, 1990-95			
Population *(%)*	1.1	1.3	1.8
Labor force *(%)*	1.1	1.4	1.9
Most recent estimate *(latest year available since 1989)*			
Poverty: headcount index *(% of population)*	11	..	..
Urban population *(% of total population)*	30	31	28
Life expectancy at birth *(years)*	69	68	63
Infant mortality *(per 1,000 live births)*	29	36	68
Child malnutrition *(% of children under 5)*	17	17	38
Access to safe water *(% of population)*	71	67	66
Illiteracy *(% of population age 15+)*	19	17	35
Gross primary enrollment *(% of school-age population)*	118	117	105
Male	120	120	112
Female	116	116	98

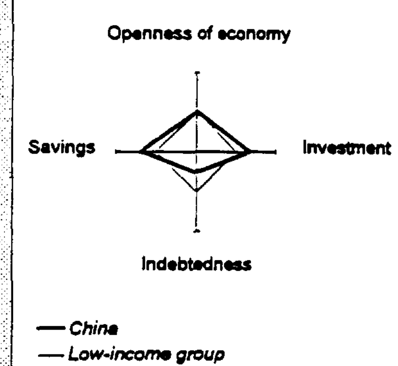
Development diamond*



KEY ECONOMIC RATIOS and LONG-TERM TRENDS	1975	1985	1994	1995
GDP *(billions US$)*	160.3	304.9	522.2	663.3
Gross domestic investment/GDP	30.3	37.8	42.1	40.5
Exports of goods and non-factor services/GDP	5.2	9.2	24.0	22.2
Gross domestic savings/GDP	30.6	33.1	44.0	43.2
Gross national savings/GDP	30.6	33.5	44.0	42.9
Current account balance/GDP	-0.2	-3.9	1.4	2.3
Interest payments/GDP	–	0.2	0.7	0.8
Total debt/GDP	..	5.5	19.3	17.9
Total debt service/exports	..	8.3	8.9	9.2
Present value of debt/GDP	..	..	17.1	..
Present value of debt/exports	..	..	71.2	–

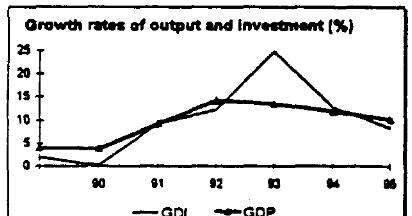
(average annual growth)	1975-84	1985-95	1994	1995	1996-04
GDP	7.7	9.5	11.8	10.2	8.5
GNP per capita	7.0	8.0	10.4	8.9	7.7
Exports of goods and nfs	20.2	13.7	28.6	18.2	8.6

Economic ratios*



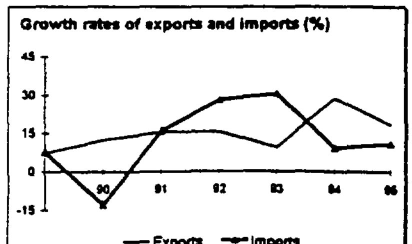
STRUCTURE of the ECONOMY *(% of GDP)*	1975	1985	1994	1995
Agriculture	32.0	28.4	21.0	20.5
Industry	42.8	43.1	47.2	48.0
Manufacturing	31.6	35.4	37.0	37.6
Services	25.2	28.5	31.8	31.5
Private consumption	61.9	53.7	42.7	47.6
General government consumption	7.6	13.2	13.2	9.2
Imports of goods and non-factor services	5.0	13.9	22.0	19.5

Growth rates of output and investment (%)



(average annual growth)	1975-84	1985-95	1994	1995
Agriculture	5.1	4.1	4.0	4.0
Industry	10.0	12.7	17.4	13.0
Manufacturing	13.1	12.3	17.2	13.0
Services	8.7	9.4	8.2	10.1
Private consumption	7.5	8.5	5.7	18.9
General government consumption	8.5	7.7	6.6	..
Gross domestic investment	8.9	9.4	12.8	8.4
Imports of goods and non-factor services	24.1	9.2	8.9	10.8
Gross national product	8.5	9.5	11.6	9.9

Growth rates of exports and imports (%)



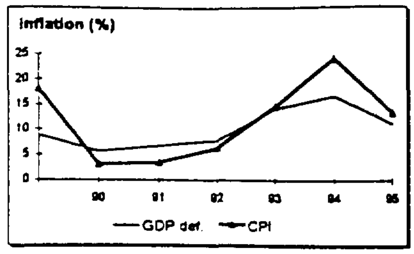
Note: 1995 data are preliminary estimates.

* The diamonds show four key indicators in the country (in bold) compared with its income-group average. If data are missing, the diamond will be incomplete.

China

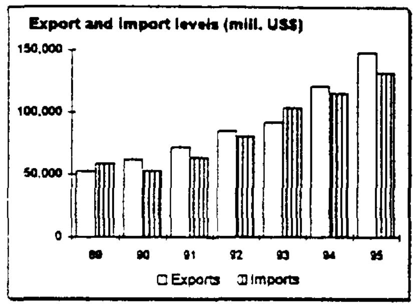
PRICES and GOVERNMENT FINANCE

	1975	1985	1994	1996
Domestic prices				
(% change)				
Consumer prices	0.2	9.3	24.1	13.2
Implicit GDP deflator	-0.9	10.1	16.6	11.0
Government finance				
(% of GDP)				
Current revenue	..	25.5	12.4	12.3
Current budget balance	..	6.7	0.4	0.3
Overall surplus/deficit	..	-0.5	-1.6	-1.7



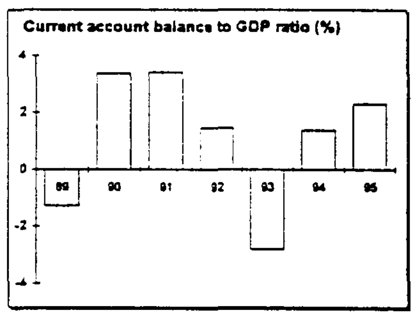
TRADE

	1975	1985	1994	1996
(millions US$)				
Total exports (fob)	..	27,350	121,038	148,750
Food	..	3,803	10,017	12,828
Petroleum	..	7,132	4,061	4,152
Manufactures	..	13,522	101,331	127,638
Total imports (cif)	..	42,252	115,693	132,308
Food	..	1,881	4,996	6,562
Fuel and energy	..	172	4,034	5,244
Capital goods	..	18,694	55,720	55,882
Export price index *(1987=100)*	..	92	124	130
Import price index *(1987=100)*	..	78	122	128
Terms of trade *(1987=100)*	..	117	102	102



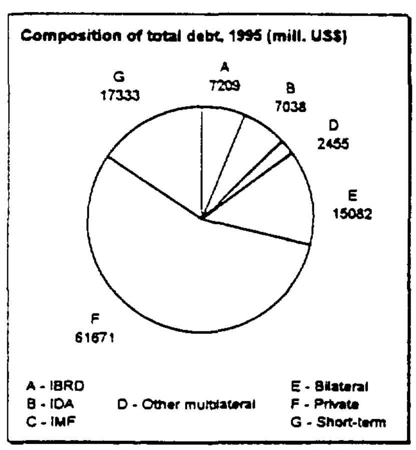
BALANCE of PAYMENTS

	1975	1985	1994	1996
(millions US$)				
Exports of goods and non-factor services	7,828	28,163	118,811	147,155
Imports of goods and non-factor services	8,097	41,149	111,472	129,279
Resource balance	-269	-12,986	7,339	17,876
Net factor income	0	932	-1,018	-3,866
Net current transfers	0	171	836	724
Current account balance, before official transfers	-269	-11,883	7,157	14,734
Financing items (net)	..	9,443	23,370	8,266
Changes in net reserves	..	2,440	-30,527	-23,000
Memo:				
Reserves including gold *(mill. US$)*	..	16,881	57,794	76,592
Conversion rate *(local/US$)*	1.9	2.9	8.6	8.3



EXTERNAL DEBT and RESOURCE FLOWS

	1975	1985	1994	1996
(millions US$)				
Total debt outstanding and disbursed	..	16,696	100,536	110,788
IBRD	..	498	5,933	7,209
IDA	..	431	6,097	7,038
Total debt service	..	2,478	11,135	15,506
IBRD	..	26	679	810
IDA	..	4	50	63
Composition of net resource flows				
Official grants	..	117	332	296
Official creditors	..	1,117	3,117	2,789
Private creditors	..	2,867	8,353	5,394
Foreign direct investment	..	1,659	33,787	38,000
Portfolio equity	..	0	3,915	1,297
World Bank program				
Commitments	..	1,092	4,077	2,942
Disbursements	..	565	2,060	2,269
Principal repayments	..	0	323	364
Net flows	..	565	1,736	1,905
Interest payments	..	29	406	509
Net transfers	..	536	1,331	1,396



International Economics Department 7/18/96

Note: The dollar estimates for China's GNP per capita and GDP are taken from the World Development Indicators and are preliminary figures based on an on-going World Bank study of China's GDP. They were calculated to facilitate inter-country comparisons. Official statistics are used as the basis for all other economic analysis contained in this document.

PART II: TECHNICAL ANNEXES

ANNEX 1: BOILER TECHNOLOGY PACKAGES

The project consists of two parts:

1. Improvement of existing boilers;
2. Development of new coal-fired industrial boilers.

1. Improvement of Existing Boilers

Improved industrial boiler plants (i.e., boilers with their auxiliaries) herein are defined as 1~20 t/h industrial plants which are built on the basis of the Chinese industrial boiler designs combined with imported technologies.

1.1 Focal points of improving the existing boilers:

- Improve designs and manufacturing technologies of combustion equipment, raise manufacturing quality and assembling accuracy of grate, adopt precision casting techniques to form grate bars and other castings, improve air tightness of plenum, make wind pressure of plenum be over 50 mm H_2O, improve evenness, regulation and effectiveness of air distribution;

- Optimize necessary auxiliary equipment and accessories;

- Furnish necessary and suitable control devices and monitoring instruments;

- Improve tightness of furnace, flue and air ducts, minimize leakage of air entering flue side; and

- Improve completed boiler quality and its performance, integrate boiler house system (e.g. automatic loading and unloading systems of coal and ash, and closed handling systems of coal and ash).

1.2 General technical requirements for improved boilers to meet the following rated loads:

- Minimum Guaranteed thermal efficiency, 78 percent for Class 2 bituminous coal (if D<= 6 t/h is given >= 70 percent);

- Maximum flue gas excess air coefficient

    - <=1.5 for Class 2 bituminous coal (α<1.6 when Chinese raw coals are used)
    - <=1.6 for Class 2 anthracite (α<=1.7 when Chinese raw coal are used);

- Maximum smoke emission <=100 mg/Nm^3;

- Maximum flue gas borne CO emissions <=250 ppm; and

- When burning Class 2 bituminous coal with high sulfur content.

All other performance specifications or indices not listed here should reach or surpass the Chinese current standards, and be in conformity with related quantity stipulations for Chinese industrial boiler products. Improved boilers shall perform well at low load. When a boiler operates at 60 percent of MCR, the reduction range of its efficiency should be less than two percent, the allowed increased value of its flue gas excess air coefficient comparing with that at rated load should not be over 0.2.

1.3 Boiler Product Type

- **Subproject 1**: **Packaged water tube boiler**
  (All performance specifications are same as Subproject 2)

- **Subproject 2**: **Improved packaged firetube-watertube boiler**

  Capacity range: 1 ~ 6 t/h
  Steam pressure: 0.4 ~ 2.5 MPa
  Steam temperature: Saturated temperature ~ 350°C

  Type of combustion equipment: chain grate stoker

  Automatic control level: based on overseas small boiler and combined with Chinese condition by importing and absorbing foreign technology, an automatic control of coal and water feeding, and blow-off and safety and emission monitoring can be achieved.

  Prototype specifications: Capacity >= 4 t/h
  Steam pressure = 0.7 ~ .25 MPa
  Steam temperature: saturated temperature ~ 350°C

- **Subproject 3**: **Modular water tube boiler (burning low sulfur coal)**

  Capacity range: 6 - 20 t/h
  Steam pressure: 1.0 - 2.5 MPa
  Steam temperature: saturated temperature ~ 450°C

Type of combustion equipment: traveling grate stoker (louver or crossbeam stoker)

Automatic control level: automatic control of water feeding and blow-off, automatic combustion regulation, measuring, safety and emission monitoring instrumentation.

Prototype specifications: Capacity >= 10 t/h
Steam pressure = 1.0 ~ 2.5 MPa
Steam temperature: Saturated temperature ~ 400°C

- **Subproject 4**: **Modular water tube boiler burning high sulfur coal**

It can be fluidized bed combustion (FBC) boiler or grate boiler with de-sulfurization in furnace.

Capacity range: 6 ~ 20 t/h
Steam pressure: 1.0 ~ 2.5 MPa
Steam temperature: Saturated temperature ~ 400°C

Coal type: Q^{y}_{dw} = 16,250 - 20,335 kj/kg, S^{y} = 2 - 6 percent
Minimum Guaranteed Thermal Efficiency: >= 82 percent for BFC

Emissions control: at ca/s <= 2, minimum de-sulfurization rate >= 50 percent; and SO_2<200 ppm

Automatic control level: automatic control of water feeding and blow-off, amplified combustion automatic regulating, measuring, safety and emission monitoring instrument.

Prototype specifications:
Capacity range: 10 ~ 20 t/h
Steam pressure = 1.0 ~ 2.5 MPa
Steam temperature: Saturated temperature ~ 400°C

- **Subproject 5**: **Packaged and modular hot water boiler with water tube**

Capacity range: 0.7 ~ 14 MW
Outlet pressure of water: 0.4 ~ 1.6 MPa
Outlet/inlet temperature of water: 95/70 ~ 150/90°C

Type of combustion equipment: < 7 MW, chain grate stoker; >= 7 MW, Traveling grate stoker.

Automatic control level: simple and convenient automatic control of water making outlet/inlet water temperature adjusting and instruments for measuring, safety and emission monitoring.

Prototype specifications:
Capacity = 7 MPa
Outlet water pressure: 0.7 ~ 1.6 MPa
Outlet/inlet water temperatures = 95/70 ~ 150/90°

- **Subproject 6: Packaged and modular extended furnace water and fired tubes boiler**

  Capacity range: 4 ~ 20 t/h
  Steam pressure: 0.4 ~ 2.5 MPa
  Steam temperature: Saturated temperature ~ 400°C

  Type of combustion equipment: Chain grate stoker

  Automatic control level: Simple and convenient automatic control and necessary monitoring instruments.

  Prototype specifications: Capacity = 6 t/h
  Steam pressure = 0.7 ~ 2.5 MPa
  Steam temperature: Saturated temperature ~ 400°C

2. **The development of new coal-fired industrial boilers** incorporating proven foreign boiler design. 10 ~ 100 t/h IB plants, suitable for burning Chinese coals, are to be developed based on such foreign technologies as internationally proven traveling grate stoker firing, spreader stoker firing and fluidized bed combustion.

2.1 Key points to be considered

- Overall design technologies of large capacity traveling grate stoker hot water boiler including fluid flow (especially water circulation) calculations, design approaches, CAD (computer aid design) software.
- Calculating methods and CAD software for designing the boiler with a traveling grate spreader stoker such as stress and strength calculations, thermal calculation, draft loss calculation.
- Structural design, manufacture, assembly technology and manufacturing standards/ code/ criteria for the spreader and the traveling grate stoker.

- Design approach of secondary air entering a furnace, design approach of refiring system, structured design and manufacturing technology for both the secondary air fan and the small flowage wind fan with low noise and high pressure head.
- FBC boiler: thermal calculation, draft loss calculation and CAD software.
- Structural design and manufacturing technology of the gas and solid separator and material return system.
- Technology and equipment for crushing and screening coal and limestone.
- Ash cooling and treating system.
- In-furnace de-sulfurization and de-NO_x technologies.
- Computerized design approaches of combustion and feeding water control system;
- Technology of bag-type collectors and filtering materials.
- Design and manufacturing technology of measurement meters and monitoring instruments such as steam flowage meter, online monitors for monitoring smoke, SO and CO_2 emission.

2.2 Types of coal-fired industrial boiler to be developed:

- **Subproject 7: Medium capacity steam boiler**

  Capacity range: 35 ~ 100 t/h.
  Steam pressure: 1.0 ~ 5.3 MPa.
  Steam temperature: Saturated temperature ~ 450°C
  (The steam parameters should be matched with the requirements of domestic turbines.)

  Suitable coal: Class 2 bituminous coal

  Q^y_{dw}= 17,700 ~ 21,000 kj/kg (4,228 ~ 5,016 kcal/kg), V^r >20 percent

  Design coal: Class 2 bituminous coal

  Type of burning equipment: spreader and reversed traveling stoker, matched with the secondary air technology and fly ash reburning device.

  Minimum Guaranteed Thermal Efficiency: 80 percent at MCR
  Maximum flue gas excess air coefficient: $\alpha = 1.5$

Maximum dust emission =< 100 mg/Nm^3
Maximum CO emission =< 250 ppm

Automatic control level: automatic water feeding and blow-off, automatic combustion control and automatic monitoring and alarm of over-emission etc. All of these should reach the current average performance level of the similar products made in developed countries.

Prototype specifications: capacity >= 65 t/h, pressure >= 3.82 MPa, superheat steam temperature = 450°C

- **Subproject 8: Medium capacity hot water boiler**

Capacity range: 7 ~ 70 MW
Outlet water pressure: 0.7 ~ 2.5 MPa
Outlet/inlet water temperature: 95.70 ~ 180/110°C

Suitable coal: Class 2 bituminous coal
Design coal: Class 2 bituminous coal

Type of burning equipment: traveling grate stoker, matched with secondary air system.

Minimum Guaranteed Thermal Efficiency: 80 percent at MCR
Maximum dust emission <= 100 mg/Nm^3
Maximum CO emission <= 250 ppm

Automatic control level: reach higher performance levels of the similar products made in developed countries.

Prototype specifications:
Capacity >= 29 MW
Outlet water pressure = 1.25 ~ 2.5 MPa
Outlet/inlet water temperatures: 130/70 ~ 180/110°C

Subproject seven medium capacity steam boiler and subproject six medium capacity hot water boiler should have good performance at partial load operation. When they operate at 60 percent of MCR, the reductions of their efficiencies should be less than two percent compared with design efficiencies, and their flue gas excess air coefficients should not be over 1.6.

- **Subproject 9: FBC boiler**

Capacity range: 35 ~ 100 t/h
Steam pressure: 1.0 ~ 5.3 MPa
Steam temperature: Saturated temperature ~ 450°C

Turndown ratio: 50 percent

Suitable coal: Coals having high ash, high sulfur content and low heat value. Q^y_{dw}= 10,470 ~ 16,750 kj/kg (2,500 ~ 4,000 kcal/kg), S^y >= 3 percent, A^Y = 27 ~ 47 percent.
Minimum Guaranteed Thermal Efficiency: >85 percent;
Combustion efficiency: >98 percent.
Maximum flue gas excess air coefficient: $\alpha = 1.4$
Emissions control: NO_x < 180 ppm
SO^2 < 200 ppm
CO < 250 ppm
Dust concentration <= 100 mg/Nm3

Automatic control level: combustion and feed water automatic control, closed handling systems for ash and slag. Stack emission (smoke SO_2 and NO_x) monitoring should reach average performance levels of the similar product made in developed countries.

Prototype specifications:
Capacity >= 35 t/h
Steam pressure = 2.5 ~ 5.3 MPa
Steam temperature = 400 ~ 450°C

Boiler thermal efficiency at 50 percent of MCR should be higher than 84 percent and flue gas excess air coefficient should be less than 1.5.

ANNEX 2: DOMESTIC ENTERPRISE SELECTION

1. The selection of domestic enterprises to participate in the project was undertaken in two stages, i.e., the prequalification stage, and the final selection of the enterprises.

2. **Domestic Enterprise Prequalification**: The basis of the selection process of the domestic enterprises has been to introduce as much competition as possible. This is to ensure that the strongest (technical, financial, and commercial) enterprises for particular technologies are selected, and that the enterprises have "ownership" of the projects. The initial stage has been an identification procedure (carried out in parallel with qualification of international technology providers) based on the following criteria agreed with the World Bank team:

- (a) technical capability and management efficiency of the boiler enterprise;
- (b) financial viability of the enterprise;
- (c) technical soundness of the proposed project; and
- (d) the ability to present a realistic and viable project financing plan.

3. The recruitment of qualified domestic boiler manufacturers to participate in the project was undertaken through an open competition launched by the Ministry of Machinery Industry's PMO. Announcement of the project was made in local newspapers. In addition, direct contacts with enterprises were made to further solicit their interest to participate in the project. All responding enterprises were asked to prepare a prefeasibility study stating their project objectives and ways of achieving them. The enterprises were evaluated by PMO with the assistance of international boiler experts and a local financial consulting company.

4. During preappraisal, the Bank team reviewed the evaluation reports and finalized a short list of 20 prequalified domestic enterprises out of 33 applicants. The prequalified enterprises were selected to proceed to the next stage of project preparation, i.e., to undertake an international assessment tour and to prepare a feasibility study, incorporating the results of the tour and possible technical cooperation arrangements with foreign firms.

5. **Final Selection of Domestic Enterprises to participate in the Project**: The 20 prequalified domestic boiler enterprises have undertaken a technology assessment tour to

visit potential suppliers of technology from a list of 17 prequalified potential foreign technology suppliers. The results of the visit and discussions with foreign firms have been incorporated into the feasibility studies submitted by the prequalified domestic firms, which have been evaluated by PMO based on the following standards with respective weights.

Weights

(a) Qualification of domestic boiler enterprises — 1/3

- Technical qualification of the enterprises — 50%
- Financial viability of the enterprises — 50%

(b) Technology Transfer Content — 1/3

- Technical suitability — 25%
- Licensor's technology transfer experience — 10%
- Licensor's resources — 15%
  - Personnel
  - Financial Position
  - Design Offices and R&D facilities
  - Manufacturing facilities
- Licensing arrangements — 25%
  - Agreement structure
  - Training program
  - Technical assistance package
- Pricing — 25%
  - Basic know-how fees
  - Royalties
  - Technical Assistance
  - Critical components

(c) Subproject Evaluation Criteria — 1/3

- Thermal efficiency of improved model — 30%
- Economic cost/benefits analysis — 30%
  - Project economic rate of return (40%)
  - Rate of return to end-users (15%)
  - Payback period to end-users (15%)
  - GEF and total cost per ton of CO2 removed (30%)

- Local pollution reduction 20%
  Projected TSP, SO_2, NO_x emissions

- Others 20%
  Range of future applications (50%)
  Project reliability (50%)

6. The winning enterprises for each of the nine technology packages are the following:

(a) Package Water Tube Boiler (1 to 6 tph capacity)-Tianshan Boiler Works

(b) Package Water and Fire Tube Boiler (1 to 6 tph)-Yingkou Boiler Works

(c) Modular Water Tube Boiler (6 to 20 tph)-Sifang Boiler Works

(d) High Sulfur Coal Boiler (6 to 20 tph)-Jiangxi Boiler Works

(e) Package/Modular Hot Water Boiler (0.7 to 14 MW)-Changzhou Boiler Works

(f) Extended Fire and Water Tube Boiler (1 to 10 tph)-Zhengzhou Boiler Works

(g) Combined Heat and Power Steam Boiler (10 to 100 tph)-Jinan Boiler Works

(h) Modular Hot Water Boiler (7 to 70 tph)-Hangzhou Boiler Works

(i) Fluidized Bed Combustion Steam Boiler (35 to 100 tph)-Harbin Industrial Boiler Company

ANNEX 3: PROCUREMENT, DISBURSEMENT, ACCOUNTING, AUDITING AND REPORTING

Procurement

1. **Identification and Qualification of Technology Providers.** With the assistance of international consultants, MMI identified nine specific technology packages covering a range of coal fired boiler technologies including boiler designs and important ancillaries (stokers, combustion air systems, instrumentation systems, etc.). A notice requesting interested technology holders to submit qualification information was published in Development Business on December 31, 1994 and the China Mechanical and Electrical Daily, also in December 1994. Notification letters were also sent to all foreign embassies in Beijing and to industrial trade associations in various countries. Visits were made by PMO teams to companies expressing interest, and based on these visits and the information provided by the companies, technology providers were qualified based on criteria agreed between PMO and the Bank, and a qualification report was sent to the Bank.

2. **Contract Provisions.** Different technology holders may insist on very specific contract provisions and specific contract forms, whose acceptability would have to be carefully reviewed by the Bank before contract approval. Draft documents for the scope of technology transfer and general contract provisions, based on the standard documents for China for transfer of process technology have been prepared. These are intended to provide guidance to both the domestic boiler enterprises and the technology holders on the scope of services to be supplied and contract provisions that need to be agreed to.

3. A two-stage bidding process will be used for all subprojects that have two or more prequalified technology sources. Procurement of design and manufacturing technology will follow limited international bidding (LIB) procedures according to Bank guidelines. The procedures will be based on the *Instructions to Bidders* of January 1995 and revised in January 1996 from the Bank's *Standard Bidding Documents for Supply and the Installation of Plant & Equipment*, and the *Conditions Of Contract For Process Technology Procurement* that have been agreed to by the Bank and Chinese government authorities. For subprojects with only one prequalified technology source direct contracting will be used for procurement. This will also be based on the Bank's *Standard Bidding Documents for Supply and the Installation of Plant & Equipment* and the *Conditions Of Contract For Process Technology Procurement.* Those documents will be appropriately modified to meet the needs of the project.

4. MMI, the implementing agency for this project, has designated Beijing Clean Combustion Engineering Company Limited to act as MMI's agent and coordinate the procurement of imported advanced-technology aspects of the project for the boiler manufacturers participating in this project. MMI has also designated China Machine Building International Corporation (CMIC) to act as agent and coordinate the goods procurement aspects of the project between MMI and the boiler manufacturers participating in the project. CMIC is the leading organization in China for procurement of power and industrial boilers.

5. **Technology Transfer Phase 1.** A model technology transfer procurement document for subproject #9 has been reviewed, and the Bank has informed MMI that it has no objection to commencement of the bidding process. Bidding documents for the other eight subprojects are also being reviewed.

6. In Phase 1, technology rights, goods and services will be procured through limited international bidding (LIB) estimated to amount to $16.4 million. With the Bank's agreement, proprietary items are to be procured through direct contracting, estimated to amount to $6.5 million. Aggregate amounts for LIB and direct contracting cannot be determined at this stage of technology transfer.

7. **Evaluation.** At the end of Phase 1, PMO will undertake an evaluation of the demonstration units and prepare an evaluation report. The evaluation will investigate whether the demonstration units and the project enterprises have: (a) met predetermined technical performance criteria; (b) met domestic and international safety standards; (c) presented an acceptable Phase 2 production plan, including financing; and (d) prepared an adequate marketing plan. Only those enterprises that meet all four criteria will be eligible for financing under Phase 2. Should the rights to any critical components of the demonstration model be the property of a third party, a separate technology transfer negotiation would be carried out under Phase 2. Should an enterprise fail to meet the Phase 1 evaluation criteria, MMI would select an alternative subproject, satisfactory to the Bank.

8. **Technology Transfer Phase 2.** During Phase 2, the boiler enterprises that have successfully met their subproject performance criteria will procure production equipment to put the new boiler designs into production. Goods and services procured under national and international shopping are expected to amount to $3.7 million. Items costing more than $250,000, but less than $2 million, are to be procured through international shopping based on quotations from at least three suppliers, from at least two countries, up to an aggregate amount not to exceed $2,690,000. Items costing less than $250,000 are to be procured through national shopping, up to an aggregate amount not to exceed $1,000,000 equivalent.

9. Consultants for both Phases will be engaged on the basis of *Guidelines for the Use of Consultants by World Bank Borrowers and World Bank as Executing Agency*

dated August, 1981. Consultancy contracts will adhere to the Bank's Standard Form of Contract for Consultant's Services.

10. Prior review of procurement documentation by the Bank will include goods contracts costing $200,00 or more, all LIB and proprietary items and all consultancy services in excess of $100,000 for firms, and above $50,000 for individuals. The consultancy terms of reference and technical requirements regarding experience and capacity will be subject to prior review for all consultancy contracts, as will all single source contracts and amended contracts which exceed these thresholds. About 80 percent of the proceeds of the grant will be subject to prior review. For contracts not subject to prior review, post review will be carried out during project supervision, to include a minimum of 25 percent of such contracts.

Disbursement

11. The GEF Grant would be disbursed against 100 percent of expenditures for subgrants under approved subprojects. To facilitate disbursement, a Special Account in dollars with an authorized allocation of $2,200,000 equivalent (based on four months' average disbursements) would be established. The initial deposit would be limited to $1,500,000 equivalent until withdrawals reach SDR 7,000,000. The Special Account would be replenished monthly or whenever the special account is drawn down to 50 percent of its initial deposit, whichever occurs first. Disbursements would be made on the basis of statements of expenditure (SOEs) for (a) consulting service contracts valued at less than $100,000 for firms or $50,000 for individuals and (b) goods contracts of less than $200,000 equivalent. PMO would retain documents supporting the SOEs and would make this documentation available for inspection by Bank supervision missions. The projected disbursement schedule (Schedule C) is considerably shorter than the disbursement profile for standard industrial projects. A principal reason for this is that the bidding process is based on a modular approach, in which one procurement package will be used as a model for all nine subprojects. Therefore, bidding for all subprojects is expected to take place more or less in parallel. Another important reason is that GEF financing will mostly occur in Phase 1, in which the bulk of the funds will be disbursed relatively quickly for technology transfer through licensing and purchase of proprietary goods for demonstration units. The grant will finance 100 percent of subgrants to individual subprojects, 100 percent of consultant services, 100 percent of foreign expenditures for goods, 100 percent of local ex-factory expenditures for goods, and 75 percent of local expenditures for other items procured locally.

Reporting

12. During negotiations, assurances were obtained from MMI that it will furnish to the Bank: (a) an annual audit report, to be presented not later than June 30, of project accounts, the Special Account and statement of expenditures; (b) an annual progress report, to be presented not later than February 15, showing levels of achievement of performance and development impact indicators; and (c) a semiannual subproject

progress report, to be submitted by February 15 and August 15, including the physical implementation and disbursement status (planned versus actual) of each subproject.

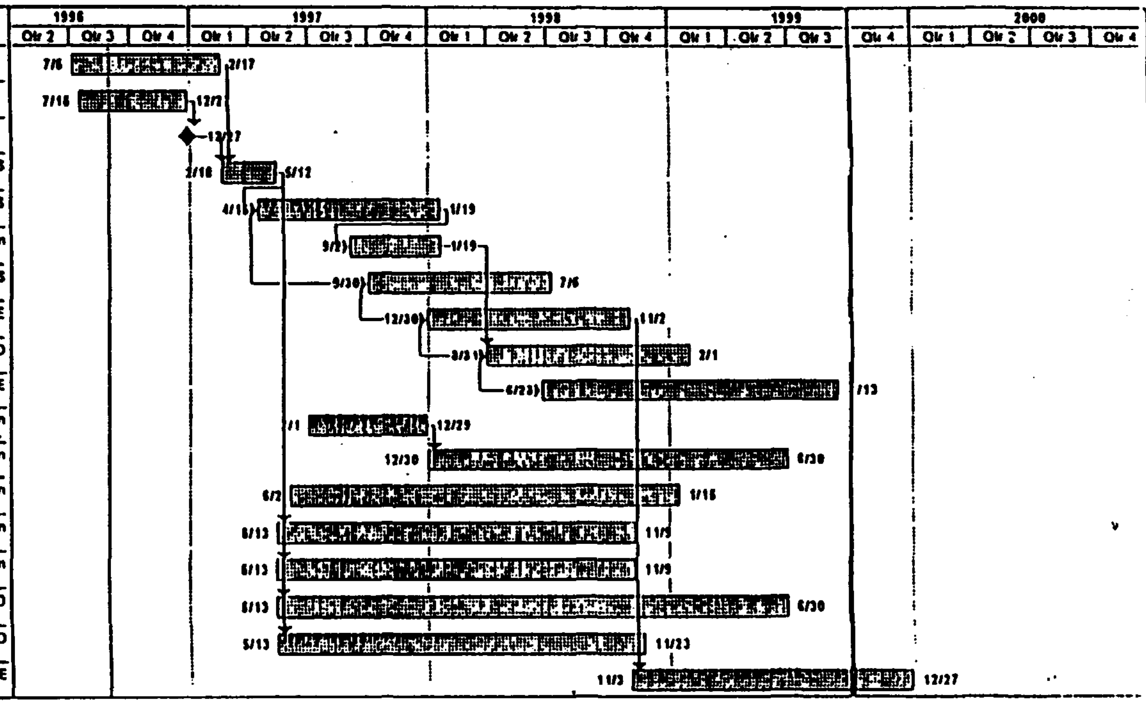
Accounting and Auditing

13. A separate project account will be maintained by MMI. PMO will monitor and consolidate financial reporting for individual subprojects, obtain annual financial statements from participating boiler manufacturers and prepare annual financial status reports for each subproject and enterprise. During negotiations, assurances were provided that this information would be available for inspection by Bank supervision missions. Auditing of the proposed project and subprojects financed by the grant will be conducted by the State Audit Administration's Foreign Funds Application Department. This arrangement is satisfactory to the Bank.

Overall Project Schedule

China
GEF Efficient Industrial Boilers Project
Project Implementation Schedule

Task Name	Duration	Resource
Technology Transfer Contracting	162d	
Grant Preparation and Approval	120d	
Project Effectiveness	0d	
Technology Training	60d	LBE,ITS
Design of Verification Units	40w	LBE,ITS
Safety Evaluation	20w	Con
Manufacture Verification Units	40w	LBE,ITS
Install Verification Units	44w	LBE
Testing and Evaluation of New units	44w	LBE,PMO
Install New Production Facilities	64w	LBE
Develop Operator Training Program	26w	Con
Train and Certify Operators	78.4w	Con
Revise IB Standards	85w	Con
Boiler Design Improvement	78w	Con
Boiler house Standards	78w	Con
Market Development	111.4w	PMO
Local Desemination Pilot	80w	PMO
Promotion of improved designs	60w	PMO,LBE



Key Responsible Organizations

China Machine-building International Corp.	CMIC	Ministry of Finance	MMI
Contractor	Con	Ministry of Machinery Industry	MOF
Global Environmental Facility	GEF	Project Management Office	PMO
International Technology Source (s)	ITS	World Bank	WB
Leading Boiler Enterprise (s)	LBE		

ANNEX 5: FINANCIAL AND ECONOMIC ANALYSIS

Least-Cost Solution

1. Improving the efficiency of industrial boilers has been identified as a high priority and low-cost means for reducing greenhouse gas emissions in China.[4] Among the options for reducing fuel use in China's industrial boiler sector are: (i) improving boiler technology, (ii) improving boiler operation, and (iii) improving the quality and consistency of coal. A two-year prefeasibility study, carried out by Chinese and international boiler experts, assessed these and other factors related to the low operational efficiency of Chinese industrial boilers and concluded that large improvements in efficiency could be made through the transfer of technology from abroad.[5] In addition, the improvement of domestic boiler design and production capabilities through technology transfer was determined to be one of the most cost-effective and immediately implementable of the options.

Economic Evaluation

2. The direct benefit to China of undertaking the project is a sustained reduction in CO_2 emissions which reduces the threat of global climate change, affecting both China and the rest of the world. The "without project" option has been shown to result in unnecessary energy use on the order of 300-500 million tons of coal over the life of the project, and excess emissions of 600-1,000 tons of CO_2. In addition to the reduction in CO_2, the project will generate substantial financial benefits to consumers in terms of lower energy expenditures and significant, though less easily quantifiable, benefits in terms of reduced TSP and SO_2 emissions. With the proper marketing and dissemination, the improved boilers are expected to increase in market share, replacing older less-efficient designs. An analysis of the industrial boiler market in China is provided in Annex 10.

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4 *China: Issues and Options in Greenhouse Gas Emissions Control,* Summary Report, Washington, December 1994.

5 *Prefeasibility Study on High Efficiency Industrial Boilers*, Subreport 11, *China: Issues and Options in Greenhouse Gas Emissions Control,* August 1994.

3. **Coal prices.** Although detailed nationwide surveys of coal prices in China have not been carried out, recent studies conducted by the Bank and other institutions show that coal prices are largely market-determined and that most end-users pay prices for coal that are close to the marginal costs of supply. Under China's former central planning system, retail prices of energy and other key commodities were set by the central government. Consequently, end-use prices were well-known in any locale; however, they bore little relationship to production, transportation and distribution costs. Since the early 1980s, energy prices have been progressively decontrolled in China. With the change to a more market-oriented economy, it is necessary to conduct detailed end-use surveys to obtain information about energy prices. As part of the China Greenhouse Gas Study, twenty-one industrial energy efficiency case studies, representing a wide range of industries and locations throughout China, were carried out.[6] In all cases, the industries were found to be paying market prices for their major energy supplies (coal and electricity). Similar results have been obtained during the preparation of the GEF Efficient Industrial Boilers Project, wherein boiler consumers were found to be paying market prices for their coal.

4. **Boiler sales price.** A key variable in the project cost-benefit analysis undertaken for boiler producers and consumers was the sales price of the new boiler. The future market price for each of the nine improved boiler models was determined by examining current market prices for boilers with different attributes and through an analysis of production costs and the benefits to consumers of using the new boiler. A detailed description of the price determination for the new boilers is provided in Annex 10. The prices of the new boilers used in the cost-benefit and incremental cost analysis are presented in Table 6 of Annex 10. In general, the range of prices for the new boiler used in the cost-benefit and incremental cost analysis are between 14 and 20 percent higher than the prices for comparable (though less efficient) existing boiler models.

5. **Rate of return analysis.** Detailed financial and economic analyses were undertaken for each of the nine subprojects. Discounted life-cycle cost-benefit tables were prepared, using enterprise- and industry-level estimates of investment and operating costs, and benefits streams based on sales revenues. Incremental ("with" minus "without" project) cash flow tables were prepared for the purpose of estimating the incremental costs of the project. The net present value (NPV), internal rate of return (IRR), and payback period (PT) calculations were carried out on an incremental project basis. For each of the nine industrial boiler subprojects, the NPV, IRR, and PT were calculated for both boiler producers and boiler consumers.

(a) **Consumers.** It was assumed that boiler consumers would be willing to pay a higher initial price for the improved boiler if they were compensated, over the lifetime of the boiler, through lower operating

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6 Ward et al (eds.), "Energy Efficiency in China: Case Studies and Economic Analysis," *Issues and Options in Greenhouse Gas Emissions Control*, Subreport No. 4, December 1994.

(primarily fuel) costs. For the new boilers to sell, it was assumed that the boiler price increase must be compensated by direct financial benefits to consumers (see Annex 10), and that the payback period for the new boiler should be no longer than for the older model. The IRR and payback period for each subproject are given in Table 1.

(b) **Producers.** Financial and economic cash flow analysis was done for producers of each of the nine boiler subprojects, based on projected lifecycle costs (investment and operating) and benefits (sales revenue) associated with the new boilers. The rates of return to producers for investing, developing, and manufacturing the new boilers were found to be in the range of 5-7 percent (see Table 1), below the 12 percent target rate of return used for project analysis in China. If the incremental costs, representing the costs of overcoming the information and technology transfer barriers for demonstrating and producing the more efficient boilers, were covered by the GEF, the rates of return for all of the boiler producers reached approximately 12 percent.

TABLE 1: ECONOMIC INDICATORS FOR THE CASE STUDY ANALYSIS

	Producers	Consumers	
	IRR (%)	IRR (%)	PT (yrs)
Subproject 1	6.73	33.74	3.95
Subproject 2	6.79	29.07	4.41
Subproject 3	6.18	27.25	4.63
Subproject 4	5.89	25.67	4.84
Subproject 5	5.70	30.64	4.24
Subproject 6	6.29	29.29	4.39
Subproject 7	6.15	31.94	4.12
Subproject 8	6.53	28.47	4.48
Subproject 9	5.97	23.01	5.26

6. **Sensitivity analysis.** A number of factors were examined for their impact on the economic analysis of the project, including the sales price of the new boiler, the market price of coal, the achieved thermal efficiency of the new boilers, and the discount rate. The analysis was found to be most sensitive to the boiler sales price and the achieved operational thermal efficiency of both the new and old boilers. While the boiler sales price effected both consumers and producers, the achieved thermal efficiency affected only consumers.

7. **Sales price**. The sensitivity analysis suggests that small increases in the sales price of the new boiler may result in a dampening of consumer demand, since the IRR falls below, and the payback rises above, comparable measures for the "without project" case. With a five percent increase in the sales price of the new boiler, the average percentage rate decrease in the IRR for consumers was 33 percent. With a five percent decrease in the sales price, the average percentage rate increase in the IRR for consumers was 48 percent. Small decreases in the sales price create financial difficulties for boiler producers, suggesting that the GEF grant is essential for reducing the risk to boiler producers, and that the producers' marketing plans must emphasize the nonprice benefits of the new boilers, such as safety, ease of use, and reduced emissions. For boiler producers, a five percent increase in sales price more than doubles the IRR, while a five percent decrease in sales price lowers the IRR to less than zero.

8. **Thermal efficiency.** The economic analysis for consumers is very sensitive to the achieved efficiency of the new boilers since cost savings are directly related to thermal efficiency gains. A 0.5 percent increase in the efficiency of the new boiler-e.g., from 68.0 to 68.5 percent net thermal efficiency-results in an 18 percent increase in the project IRR for the consumer, while a 0.5 percent decrease in the efficiency of the new boiler results in a 20 percent decline in the consumer's IRR. Because the operational thermal efficiency of the new boiler is rather intangible to consumers, especially for new products, there is considerable financial risk for consumers if the new boilers do not achieve their rated efficiency levels.

ANNEX 6: INCREMENTAL COSTS

Global Environmental Context

1. Carbon dioxide from energy consumption currently accounts for roughly four-fifths of China's total greenhouse gas emissions. Without exceptional policy measures to stem the increase, carbon dioxide emissions would increase roughly three-fold between 1990 and 2020, based on a *high-growth scenario.*[7] The increase in GHG emissions in this scenario is due primarily to a rise in coal consumption from 1.05 billion tons in 1990 to about 3.1 billion tons in 2020. In order to accommodate the three-fold increase in energy use by China, and still keep global CO_2 emissions at their 1990 levels[8], the rest of the world would need to cut its CO_2 emissions by eight percent in the year 2000 and 40 percent by the year 2020.

2. Chinese researchers have predicted that a doubling of CO_2 will have a negative impact on rice, wheat, and cotton production in China because of the combined effects of higher temperatures, increased moisture evaporation from soil, and more frequent and severe storms.[9] This prediction is consistent with the most recent modeling work by the Intergovernmental Panel on Climate Change, which estimates that agricultural production could fall by 6-8 percent worldwide, and by 10-12 percent in developing countries, with a doubling of atmospheric CO_2 concentrations. Rising sea level resulting from global warming is another concern for China and other countries with large populations living in low-lying coastal plains. According to studies by Chinese researchers, a one-meter increase in sea level, when combined with storm surge and the astronomical tide, will flood areas below a four-meter contour line in China's coastal plains, including the entire cities of Shanghai and Canton.

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7 The high-growth scenario assumes the Chinese economy grows at an average annual rate of 8.0 percent between 1990 and 2020. See *China: Issues and Options in Greenhouse Gas Emissions Control, Summary Report*, December 1994.

8 Intergovernmental Panel on Climate Change; see Houghton, Jenkins, and Ephraum, 1990.

9 *Potential Impacts of Climate Change on* China, China Greenhouse Gas Study, Subreport No. 9, September 1994.

Broad Developmental Goals

3. It has been estimated that primary energy use will need to increase two- to three-fold over the coming two-and-a-half decades in order for China to achieve average GDP growth rates slightly lower than those of the past decade. Coal is the only domestic energy resource that could meet such a large increase in energy demand. In order to achieve increases in energy supply, but avoid additional pollution-related impacts from coal burning (including the threat of global climate change), China will need to improve energy efficiency in all sectors, particularly within industry, invest heavily in clean-coal technologies and pollution control equipment, and expand the use of non-coal energy sources, including renewables.

Baseline

4. Despite the virtual lack of coal-fired industrial boilers in other industrial countries, the demand for these boilers in China is expected to continue and even grow over the coming twenty years. The Chinese Ministry of Machinery Industry estimates that the annual demand for industrial boilers-both new and replacement-is currently 85-100 thousand tons of steam per hour (ktph), and will rise to 100-125 ktph by 2000, and to 130-160 ktph by 2010.[10] Cumulative production of new and replacement boilers over the next twenty years would be in the range of 2.1 to 2.6 million tph. For the purposes of the incremental cost analysis, the direct project benefits includes the production of 432,000 tph over 20 years, representing between 17-20 percent of total expected added capacity. In the absence of global environmental considerations, this capacity would be met with existing standard boiler designs.

GEF Alternative

5. The GEF alternative proposes to improve the efficiency of industrial boilers in China, largely through the transfer from abroad of advanced technologies, designs, and production methods. In the course of project identification and development, a total of nine industrial boiler models representing a broad spectrum of sizes and applications have been identified for improvement. At full production the project enterprises would annually produce 27 ktph of new boiler capacity, resulting in a cumulative capacity over 20 years of 432,000 tph.

6. Because the enterprises that will participate in the project are among the leading boiler manufacturers in China, the efficiency of their existing boilers are already near 70 percent-well above the national average of 60-65 percent. Nonetheless, through the introduction of advanced technologies and designs from abroad, the efficiency of existing boilers from advanced producers can be raised to nearly 80 percent. More importantly, once these advanced designs are demonstrated and put on the market, other producers are

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10 *Prefeasibility Study on High Efficiency Industrial Boilers*, China Greenhouse Gas Study, Subreport No. 11, August 1994.

likely to adopt the new designs and in the process raise the overall thermal efficiency level of the industry.

System Boundary

7. One of the major problems with the production of more energy efficient equipment such as boilers is that while the research and development costs and the associated commercial risks accrue to producers, the benefits accrue largely to the users through lower operating costs. In addition to appropriation problems, there is a long time lag (12 years) between the initial project investment and the time that total energy savings are sufficient to recoup the investment. Nonetheless, because of the significant national benefits that accrue to boiler consumers in the form of fuel savings, it is necessary for the system boundary to be drawn to include both producers and consumers of energy efficiency equipment.

Incidental Domestic Benefits

8. The baseline and alternative projects both provide the same level of industrial boiler steaming and hot water capacity (ktph). However, the alternative project provides consumers with lower coal fuel bills. These benefits are readily quantifiable and provide a direct financial benefit to consumers in fuel savings over the lifetime of their boilers.

9. Other domestic benefits of the alternative project include the reduction in particulates and sulfur that result from both energy efficiency and improved emission controls. Epidemiological surveys in Chinese cities have established a clear link between the increase in morbidity and mortality and high ambient concentrations of particulates and sulfur. Although, it is difficult to quantify in financial terms the human health and other benefits of reduced particulate and SO_2 emissions, the domestic benefits are presumed to be quite large as evidenced by the tightening of national air pollution standards, increasingly strict enforcement of air pollution regulations at the local level, and the growing number of investments by municipal governments in air pollution control.

Costs

10. The incremental cost of the efficient industrial boilers project has been calculated as the difference between the baseline ("without project") and the GEF alternative ("with project"). Two sets of incremental costs have been calculated: (a) the theoretical economic incremental cost to the country as a whole, and (b) the observable incremental cost to boiler producers along with incremental costs of removing barriers to effective dissemination.

11. **Theoretical economic incremental cost.** The total (discounted) capital costs of producing 432,000 tph of boiler capacity under the baseline is estimated to be $1,836 million (constant 1994 dollars), while the total (discounted) capital costs of producing the same quantity of more energy efficient boilers under the GEF alternative is

estimated to be $2,132 million. For consumers, there is a second important difference between the old and the new boilers; i.e., the cost of operating the boilers, most importantly, coal fuel. The (discounted) operating costs, including coal consumption, of the baseline are estimated to be $11,015 million. In the absence of uncertainty and risk, perfect information, and fully functioning capital markets, the (discounted) operating costs of the GEF alternative are estimated to be $10,676 million. While the incremental capital costs of the project as a whole are $295 million, theoretical operational cost savings are $339 million. Thus, while not obtainable without removing these barriers, there is a theoretical negative economic incremental cost of the GEF project of $43 million. Under this theoretical incremental cost analysis, consumers are assumed to sacrifice all of their consumer surplus to boiler producers in order for producers to earn an acceptable rate of return (12 percent) on their investment.

12. **Incremental costs of boiler production and barrier removal.** The largest component of the incremental cost is the cost to the nine subproject boiler enterprises for acquiring advanced international technologies, adapting them, and for commercial demonstration in China. Detailed "with" and "without" project cost-benefit analyses have been prepared for each of the nine boiler subprojects to serve as the "baseline" and "GEF alternative" for calculating the project's incremental costs. Limited technical renovation investments affecting thermal efficiency have been included in the "without project" case, reflecting the prevailing trend in the industrial boiler market. Cost-benefit analysis was also conducted for boiler consumers for each of the nine boiler subprojects for the purpose of calculating the project rate of return, the payback period of the boiler investment, and the *maximum* boiler price for consumers; i.e., the price at which the rate of return and payback period for the "with" and "without" project cases are equal.

13. For boiler producers, the (discounted) baseline cost of producing 432,000 tph of capacity over twenty years has been estimated at $1,584 million, while the GEF alternative has a total cost to producers of $1,862 million, a difference of $278 million.[11] Producers also receive different income streams under the baseline and GEF alternative due to higher sales prices of the improved boilers. The additional (discounted) income received by producers of improved boilers under the GEF alternative is estimated at $248 million. After subtracting benefits from costs to producers, there is a net incremental cost of approximately $30.2 million[12] to boiler producers for undertaking the GEF alternative. Details of the costs of the subprojects are given in Annex 9, Tables 1 and 2.

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11 The difference in costs between (a) the theoretical economic incremental cost to the country, and (b) the financial incremental cost to producers, is that (a) assumes that boiler producers earn an acceptable profit on sales (12 percent rate of return on investment) resulting in the price of boilers to consumers set at the maximum (i.e., no consumer surplus), while (b) sets prices at levels the market can bear (approximately 20 percent less than the price producers need to earn a 12 percent rate of return). In addition to rate of return and payback analyses conducted for producers and consumers, future boiler price estimates were generated based on detailed surveys of the current industrial boiler market (see Annex 10).

12 The incremental cost was calculated at 256.7 million yuan. The January, 1995 exchange rate of 8.5 Y/$ was used in the analysis.

14. A second set of costs of the GEF alternative is for overcoming the numerous barriers to the broad dissemination of the advanced boilers throughout China and to ensure that the improved boilers are adopted by consumers. Training programs for industry representatives, dissemination and marketing activities, targeted policy studies, are described in the text and are critical to the sustainability of the project. The incremental cost of these components-those that would not be undertaken without the project-has been estimated at $1.29 million.

15. The project management office (PMO) will oversee both monitoring and evaluation and project administration functions. The incremental cost of these activities over the six-year life of the GEF project is estimated at $1.31 million.

Benefits

16. The financial and economic benefits of the project are discussed in Annex 5, while the local and global environmental benefits are discussed in Annex 9.

ANNEX 7: PROJECT PERFORMANCE, MONITORING AND EVALUATION

1. Monitoring of the project implementation progress will be the responsibility of the PMO. The PMO appointed a company under MMI (Beijing Clean Combustion Engineering Co. Ltd.) to assist in carrying out the monitoring and evaluation of implementation performance indicators summarized below:

- **Output/Outcome Indicators** will track the predetermined performance criteria for model boiler units at the completion of Phase 1. Monitoring indicators include (a) minimum thermal efficiency, (b) reduced dust emissions, and (c) reduced SO_2 emissions of the improved boiler models at subproject completion, which varies among the nine technical packages in accordance with the Project Implementation Schedule (PIS). After the model boilers are built, PMO will undertake an evaluation of each model boiler to assess whether they meet the predetermined technical performance criteria and safety standards. Only those enterprises which meet the criteria will receive funds to allow them to proceed to Phase 2 of mass producing the new boiler.

- **Development Impact Indicators** measure the success of the project as they relate to the objectives of the project. Three sets of development impact indicators are developed to link to the three objectives of the project as follows:

  (a) *Objective 1: Improvement of thermal efficiency*
  Improved coal utilization: reduce CO_2 emissions due to higher thermal efficiencies in coal fired industrial boilers

  (b) *Objective 2: Mass production of demonstration model boiler*
  Increased new boiler production and sales volume

  (c) *Objective 3: Dissemination of new boiler technologies*
  Increased the ratio of steaming capacity of new boilers to total boilers in the industry.

2. The nature of this project is such that impact of the reduction of CO_2 emissions will be measured only two years after the project is completed (2002), because the reduction in the interim years will be minimal. Participating boiler manufacturers are

therefore being required to keep track of the thermal efficiency of the boilers that they produce and sell, including the verification unit, starting in Phase 2 when mass production is initiated, until 2002. Specifically, as part of their subproject completion report, they should include information on the amount of coal use per steam-ton of output from a sample of new boilers that they produced and sold during project implementation.

3. PMO would be responsible for the preparation of annual reports using the above project activities and key performance indicators and in accordance with the PIP in assessing the implementation progress. The report would also identify possible problems or impediments and make specific recommendations for early remedial actions. The Bank will monitor the implementation activities during project supervisions and, in addition, focus on assessing the project outcome and development impact indicators as they relate to the project development objectives.

CHINA: GEF EFFICIENT INDUSTRIAL BOILERS PROJECT
PERFORMANCE MONITORING AND EVALUATION
DEVELOPMENT IMPACT INDICATORS

Project Objectives	Key Performance Indicators	Unit	Base Year 1995	1997	1998	1999	2000	2001	2002
1. Improvement of thermal efficiency of small & medium scale coal-fired industrial boilers	1. **Improved coal utilization**: reduce CO_2 emissions due to improved coal utilization in industrial boilers (coal consumption/kg-hr)	kg/hr	#1=1,187 #2=1,187 #3=1,857 #4=3,700 #5=1,860 #6=1,190 #7=14,470 #8=16,020 #9=18,160						1,092 1,092 1,710 3,408 1,710 1,092 13,319 14,739 16,707
2. Mass production and sale of new boilers by project enterprises	2. **Increased new boiler production and sales volume** of all subproject enterprises (in steam tons) /a	Steam -tons	0	68	2,030	9,620	17,940	23,300	27,200
3. Dissemination of new boiler technologies throughout China	3. **Increased steaming capacity ratio of new boilers** = tons of steam produced by new boilers / tons of steam produced by total boilers in the industry /b	%	0	0.1	2.2	9.8	19	24.8	35.1

/a Steam tons produced by all subproject participating enterprises.
/b Steam tons produced by all boiler enterprises in the industry.

OUTPUT/OUTCOME INDICATORS

Project Objectives	Key Performance Indicators	Baseline - 1995 (by subproject)	Target (by subproject)	Impact (by subproject)
Improvement of thermal efficiency of small & medium scale coal-fired indus. boilers	a) Demonstration of higher thermal efficiencies in model units at 100% / 60% load	a) # 1=71% # 2=71% # 3=71% # 4=75% # 5=72% # 6=71% # 7=72% # 8=72% # 9=78%	a) # 1=78/76% # 2=78/76% # 3=78/76% # 4=82/80% # 5=78/78% # 6=78/76% # 7=80/78% # 8=80/78% # 9=85/84%	a) July 1999 July 1999 Nov. 1999 Nov. 1999 Nov. 1999 Nov. 1999 Jan. 2000 Jan. 2000 Mar. 2000
	b) Demonstration of reduced dust emissions in model units.	b) # 1= 400 mg/Nm^3 # 2= 400 mg/Nm^3 # 3= 300 mg/Nm^3 # 4= 300 mg/Nm^3 # 5= 300 mg/Nm^3 # 6= 400 mg/Nm^3 # 7= 200 mg/Nm^3 # 8= 200 mg/Nm^3 # 9= 200 mg/Nm^3	b) 100 mg/Nm^3 for all subprojects except #4 #4 = 200 mg/Nm^3	b) July 1999 July 1999 Nov. 1999 Nov. 1999 Nov. 1999 Nov. 1999 Jan. 2000 Jan. 2000 Mar. 2000
	c) Demonstration of reduced SO_2 emission in model units	c) # 4= zero reduction # 9= zero reduction	c) # 4= 80% reduction # 9= 90% reduction	c) Nov. 1999 Mar. 2000

ANNEX 8: SOCIAL ASSESSMENT AND STAKEHOLDER CONSULTATION

Identifying and Involving Stakeholders

1. **Stakeholder Identification.** During project identification and preparation, key stakeholders were identified. The key stakeholders in the project are: (a) consumers or users of industrial boilers, both current and prospective; (b) industrial boiler manufacturers; (c) MMI, in setting design standards, regulating the manufacture of industrial boilers, and disseminating best-practice within the industry; (d) local governments involved in commissioning, testing, and monitoring industrial boilers for safety and environmental compliance; (e) domestic and international research institutes involved in design and testing of new boiler models; (f) international industrial boiler technology suppliers; and, (g) the Bank.

2. An expert group, headed by MMI and composed of major domestic and international stakeholders, prepared a prefeasibility study which identified the major technical deficiencies of current Chinese industrial boilers and recommended specific measures for improvement. The same expert group was involved in the design of the project, including the selection of the specific boiler models to be included in the project. Chinese industrial boiler manufacturing enterprises were informed of the project through a trade publication, and were invited to participate through a competitive review and selection process. International boiler technology suppliers were also informed of the project through an announcement in the World Bank publication, *Development Business*, and were asked to submit letters of intention and documentation to participate.

3. The primary grant recipients of the project will be nine competitively-selected industrial boiler manufacturing enterprises identified in Annex 2. GEF grant resources of approximately $30.2 million will be used to procure boiler technology licenses, consulting services, and equipment for the purpose of building a model unit in Phase 1 of the project, and for upgrading their production lines to mass produce the model unit under Phase 2. A secondary group of grant recipients will be domestic consulting firms and research institutes which would carry out the technical assistance under the project for the purpose of disseminating the efficient industrial boiler technologies. Grant resources of approximately $2.6 million are allocated for technical assistance and for project administration.

4. The primary domestic beneficiaries of the project are industrial boiler users, urban residents currently exposed to high levels of air pollutants from industrial boilers, and all groups exposed to future climate change impacts in China. Industrial boiler users will benefit primarily through reduced coal fuel bills, but also through increased safety, reliability, ease of use, and reduced emissions, achieved through embodied technological improvements in the new boiler designs. Urban residents will benefit from the project due to reductions in emissions of particulates and sulfur from the new boiler designs. The potential impacts of climate change on China, and the affected groups, is contained in a study by the same name prepared as part of the China Greenhouse Gas Study.[13]

Relevant Social Issues

5. **Public information.** The provision of information to all major stakeholders during project identification and design was a key element in achieving the broad level of participation in the project. During project implementation, public information will be provided to prospective boiler consumers on the range of benefits of the improved boilers through a broad-based marketing and dissemination program. Once the model units have been proven, information will also be provided to other boiler producers in China to assist in spreading the technical improvements throughout China.

6. **Local air pollution.** Local environmental and planning agencies, especially those in highly polluted municipalities, will be especially important for marketing and disseminating the improved boilers. As noted in Part I, energy efficiency improvements alone are not sufficient to market new technologies. However, other attributes, particularly the potential for major reductions in local air pollutants, will be a critical factor for disseminating the new boilers if this benefit can be properly demonstrated to local governments. One of the technical assistance components will establish a pilot marketing program for the improved boilers in municipalities with severe air pollution problems, such as Chongqing. With the cooperation of both national and local planning and environment agencies, measures for promoting adoption of more efficient and cleaner boilers, including stricter enforcement of environmental regulations, will be evaluated and implemented on a trial basis.

7. **Behavioral change.** Like other energy efficiency projects, full success cannot be achieved through technology changes alone, but require changes in human behavior. In the case of industrial boilers, operation of the boilers is an important factor in achieving the energy efficiency potential of improved boilers. The project will address boiler operation through the training of the boiler manufacturers in proper operating procedures of the new boilers, through upgrading of customer service provided to boiler consumers, and through the establishment of a boiler operator training program and certification program including a focus on energy efficiency.

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13 Chinese Research Institute of Environmental Sciences, "Potential Impacts of Climate Change on China," *Issues and Options in Greenhouse Gas Emissions Control*, Subreport No. 9, September 1994.

8. **Equity.** Because the reduction of CO_2 emissions and the threat of global climate change benefits all peoples, the broad project goals are very equitable. To the extent that the demand for industrial boilers remains concentrated in urban areas in China, and in regions of the country with a concentration of light industrial and space heating development, the project will disproportionately benefit these regions. However, these same regions have borne the major costs of inefficient and highly polluting industrial boilers in the past, as evidenced by above-average rates of morbidity and mortality resulting from high ambient concentrations of particulates and sulfur.

ANNEX 9: ENVIRONMENTAL ANALYSIS

Background

1. Industrial boilers outside the electric power sector consume approximately one-third of China's total coal, and are responsible for an even greater share of both particulate and sulfur emissions. The operational thermal efficiency of Chinese industrial boilers is low, with the typical average efficiency reaching only 60-65 percent. In contrast to the typical international situation, where typical small and medium-sized boilers consume oil or natural gas, more than 95 percent of Chinese industrial boilers consume coal. In 1990, industrial boilers consumed some 350 million tons (Mt) of coal, compared to 250 Mt by the electric power sector. If the operational efficiency of Chinese industrial boilers could reach international industrial boiler efficiency levels (for similarly-sized units), annual coal consumption by Chinese industrial boilers could be reduced by some 60 Mt.

Project Description and Objective

2. The project will introduce advanced international boiler designs and manufacturing techniques to China's industrial boiler industry. Coal-fired steam and hot water boilers with a capacity of between 1-100 tph, and a working pressure from 0.4-5.3 MPa comprise over 90 percent of China's industrial boilers, and will be the target of the GEF project. Existing Chinese boiler designs will be upgraded and new international designs will be introduced through the project. Through technology licensing and other technology transfer arrangements, Chinese industrial boiler manufacturers will design and manufacture a model unit during Phase 1 of the project. The model units will be evaluated according to their ability to meet technical and environmental standards, and for the boiler manufacturers to demonstrate a viable production, financing, and marketing plan for Phase 2, which will include the mass production and marketing of the improved industrial boiler models. Technical assistance will be provided to the industrial boiler sector for: (i) improving boiler operation through training and the establishment of a certification program, (ii) introducing new standards for industrial boilers covering thermal efficiency, safety, emissions, and coal quality, (iii) broadly disseminating the higher efficiency boiler models throughout the country.

3. The primary objective of the GEF project is to reduce coal use of Chinese industrial boilers by improving their thermal efficiency. The GEF Efficient Industrial Boilers project will replace current boilers with higher-efficiency and less-polluting models. By improving the efficiency of industrial boilers, the amount of coal consumed by the sector will be reduced, which will result in lower emissions of particulates and sulfur. In addition to the particulate and sulfur reduction gains from energy efficiency improvements, the new boilers will introduce a number of emission control technologies, including multicyclones and baghouses for particulate removal, and precombustion coal briquetting for both particulate and sulfur control. Two of the nine boiler models will be FBC-type boilers, which have high sulfur-removal capabilities. Improving boiler operation will help to raise the operational efficiency of Chinese industrial boilers. The quality of coal is another important factor for raising the thermal efficiency of Chinese industrial boilers; coal quality standards for industrial boilers will be reviewed and recommendations for revision made under the technical assistance for the project.

Administrative, Institutional, and Policy Framework

4. Over the past fifteen years, China has taken significant steps in establishing environmental policies and an environmental regulatory system. The National Environmental Protection Agency (NEPA) oversees national environmental policy, works with the environmental protection units within the ministries and state enterprises, and sets the overall policies and regulations governing provincial and municipal environmental protection bureaus.

5. A national-level Climate Change Coordination Group was created in February 1990 and charged with overall policy formulation on the greenhouse gas issue. Several climate change mitigation studies have been completed by the Government of China, including one supported by the GEF.[14] The GEF-financed study, which involved a comprehensive analysis of GHG abatement options in China and their relative costs, concludes that improving industrial boilers through technology transfer and demonstration offers the greatest potential for reducing large amounts of CO_2 in China in a very low-cost way.

6. Although comprehensive laws, regulations and standards for most pollutants (including TSP and SO_2) have been in place in China for many years, enforcement of these laws and standards at the local level, where the bulk of environmental policy takes place, remains a difficult challenge. Providing local Environmental Protection Bureaus with a partial technical solution in the form of cleaner and more efficient boilers would be an important step in strengthening environmental compliance. The project will also provide technical assistance to national and local environmental institutions for establishing a pilot program for disseminating new boiler models at the local level.

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[14] See *China: Issues and Options in Greenhouse Gas Emissions Control, Summary Report*, December 1994.

Emissions from Existing Industrial Boilers

7. **Carbon dioxide.** Emissions of carbon dioxide (CO_2) from industrial boilers are directly related to the thermal efficiency of the boiler. The average thermal efficiency achieved by industrial boilers is very low by international standards due to inefficient designs and manufacturing techniques, suboptimal operation, and poor and inconsistent fuel quality. Surveys of boiler operational efficiency conducted in 1992 as part of the China Greenhouse Gas study found that typical efficiency levels of boilers rarely surpassed 70 percent, and that the average efficiency of the boilers examined was in the range of 60-65 percent. Currently, CO_2 emissions from the industrial boiler sector in China amount to about 715 million tons of carbon (Mt CO_2), or about 28 percent of China's total CO_2 emissions from energy consumption. Simple calculations show that China could reduce CO_2 emissions from the industrial boiler sector by 15-20 percent if typical international efficiency levels could be reached, which in turn would reduce China's total CO_2 emissions by five percent.

8. **Particulates and sulfur.** The control of particulates from industrial boilers is currently limited to simple and generally inefficient cyclones. Annual particulate emissions from industrial boilers are estimated at about 6.2 million tons, accounting for some 37 percent of total national particulate emissions. There are currently no controls on the emission of SO_2 by industrial boilers in China, though a number of domestic designs for FBC boilers have been developed, with limited success, and some areas have begun experimenting with sulfur emission fees. Total annual sulfur emissions by the industrial boiler sector are currently about 5.1 million tons, contributing about 39 percent of China's total sulfur emissions.

9. Given the expectation in China for increasingly strict standards on TSP and SO_2 from industrial boilers, existing boiler designs would need to be retrofitted with additional pollution control equipment (such as cyclones and baghouses for TSP removal) and some new technologies would gain market share (such as domestically-designed FBC boilers for SO_2 control). Currently, most industrial boilers can only meet the country's lowest standards (Class III), and thus can generally not be located in urban and residential locations, where Class I and II standards apply.

Environmental Improvements With The Project

10. **Carbon dioxide.** The average thermal efficiency of Chinese industrial boilers is expected to increase significantly with the project. Whereas the average national thermal efficiency levels for the nine comparable subproject boilers is in the range of 64 to 72 percent, the target efficiencies for the subprojects is between 78 and 85 percent; a gain of about 14 percent. It should be pointed out the Chinese boiler enterprises participating in the project currently produce boilers that have thermal efficiencies significantly higher than China's national average; for the nine project boilers the thermal efficiency of existing models is in the range of 71 to 78 percent. China's leading boiler enterprises, both technically and financially, were chosen to participate in the project since they will

have the highest chance of success in transferring advanced technologies from abroad and for being able to produce and market the new boiler models. The direct project gains in thermal efficiency are therefore in the range of seven to eight percent. However, because the improved boilers are expected to gain market share in China, and replace average and below-average boilers, the thermal efficiency of China's overall industrial boiler stock is estimated to increase from 60-65 percent to between 70-75 percent.

11. Both direct CO_2 savings and indirect, or programmatic, CO_2 savings are presented in Table 3. Direct CO_2 savings from the program are estimated to be 181 Mt CO_2. Programmatic CO_2 savings are estimated to be 456-824 Mt CO_2. Together, CO_2 reductions over the life of the project are estimated to be 637-1,005 Mt CO_2.

12. **Particulates and sulfur.** Particulate emissions will be reduced in each subproject through reduced coal consumption, coal preparation, and the use of advanced cyclones and baghouses. Particulate emissions from the nine boiler subprojects are expected to be reduced from a range of 200 to 400 mg/Nm3 to less than 100 mg/Nm3 for all subprojects. Direct TSP reductions from the project are estimated at 4.55 Mt, of which 0.57 Mt is from reduced coal use and 3.98 Mt is from improved efficiency of collectors. Two of the nine subprojects will be fluidized bed combustion boilers, which it is estimated will reduce sulfur emissions by 80-90 percent. Direct SO_2 reductions from the project are estimated at 25.36 Mt, of which 94 percent of the reduction is from the two FBC boiler models and the remainder is reduced sulfur emissions due to reduced coal consumption. Particulate and sulfur reductions over time and by subproject, are presented in Tables 1 and 2, respectively.

Demonstration Units

13. Under Phase I of the project, up to nine verification boilers are to be commissioned. At present, the exact location of the demonstration units is not known, since the participating boiler enterprises were not required to submit this information for their feasibility studies. Prior to construction of the verification units, the appropriate local environmental approvals must be obtained, as would approvals for any new industrial boiler.

TABLE 1: SUMMARY: TOTAL INCREMENTAL CASH FLOW
(Y million)

Year	Annual Production (ktph)	Cumulative Production (ktph)	Put to Use (ktph)	Consumers: Total incr. Investment -----	Consumers: Total incr. Operating -----	Consumers: Net Cost -----	Consumers: Cumulative Net Cost -----	Producers Net Cost -----	Total Coal Saving (ktce)	Emission Reduction: CO_2 (k tons)	Emission Reduction: C-CO_2 (k tons)	Emission Reduction: SO_2 (k tons)	Emission Reduction: TSP (k tons)	Emission Reduction: TSP /a (k tons)	Emission Reduction: TSP /b (k tons)
1	0	0	0	0.00	0.00	0.00	0.00	470.46	0	0	0	0	0	0	0
2	0	0	0	0.00	0.00	0.00	0.00	146.06	0	0	0	0	0	0	0
3	0	0	0	0.00	0.00	0.00	0.00	113.67	0	0	0	0	0	0	0
4	9,000	9,000	0	152.74	0.00	152.74	152.74	0.17	0	0	0	0	0	0	0
5	18,000	27,000	9,000	305.48	-43.73	261.75	414.49	-31.64	188	507	138	71	13	2	11
6	27,000	54,000	27,000	458.22	-131.19	327.03	741.52	-63.45	564	1,520	415	213	38	5	33
7	27,000	81,000	54,000	458.22	-262.38	195.84	937.36	-94.00	1,128	3,040	829	426	76	10	67
8	27,000	108,000	81,000	458.22	-393.57	64.65	1,002.01	-94.00	1,692	4,560	1,244	639	115	14	100
9	27,000	135,000	108,000	458.22	-524.76	-66.54	935.47	-94.00	2,256	6,080	1,658	852	153	19	134
10	27,000	162,000	135,000	458.22	-655.96	-197.74	737.73	-94.00	2,819	7,597	2,072	1,065	191	24	167
11	27,000	189,000	162,000	458.22	-787.15	-328.93	408.80	-94.00	3,383	9,117	2,486	1,278	229	29	201
12	27,000	216,000	189,000	458.22	-918.34	-460.12	-51.32	-94.00	3,947	10,637	2,901	1,492	268	34	234
13	27,000	243,000	216,000	458.22	-1,049.53	-591.31	-642.63	-94.00	4,511	12,157	3,316	1,705	306	38	268
14	27,000	270,000	243,000	458.22	-1,180.72	-722.50	-1,365.13	-94.00	5,075	13,677	3,730	1,918	344	43	301
15	27,000	297,000	270,000	458.22	-1,311.91	-853.69	-2,218.82	-94.00	5,639	15,197	4,145	2,131	382	48	334
16	27,000	324,000	297,000	458.22	-1,443.10	-984.88	-3,203.70	-94.00	6,203	16,717	4,559	2,344	421	53	368
17	27,000	351,000	324,000	458.22	-1,574.29	-1,116.07	-4,319.77	-94.00	6,767	18,237	4,974	2,557	459	58	401
18	27,000	378,000	351,000	458.22	-1,705.49	-1,247.27	-5,567.04	-94.00	7,331	19,757	5,388	2,770	497	62	435
19	27,000	405,000	378,000	458.22	-1,792.95	-1,334.73	-6,901.77	-94.00	7,706	20,768	5,664	2,912	523	65	457
20	27,000	432,000	405,000	458.22	-1,836.68	-1,378.46	-8,280.23	-94.00	7,894	21,274	5,802	2,983	535	67	468
TOTAL	432,000			7,331.52	-15,611.75	-8,280.23	-8,280.23	-680.73	67,103	180,842	49,320	25,356	4,550	571	3,979
ENPV				2,041.28	-3,038.21	-996.93	Payback	-680.73							
EIRR						25.43%	11.89	6.23%							

/a TSP emission reductions due to lower coal consumption.
/b TSP emission reductions due to improved control technologies.

TABLE 2: OVERALL RESULTS SUMMARY

	Case 1	Case 2	Case3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Total
1. Final Capacity of New Boiler Production (t/h)	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	27,000
2. Total New Boiler Operating on Market (t/h)	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	378,000
3. Efficient Boiler Production Total Investment (Million Yuan)	57.31	86.25	74.96	71.71	77.25	83.62	114.13	95.92	159.07	820.22
4. Boiler Production Net Present IC (Million Yuan)	20.99	24.62	23.41	22.10	25.63	25.35	36.05	28.48	50.11	256.74
5. Total Coal Savings (k tce)	8,989.00	6,191.12	7,522.08	6,278.30	5,579.47	7,176.56	9,836.49	6,457.58	9,071.78	67,102
6. Total Carbon Saving (k t-Carbon)	6,606.92	4,550.47	5,528.73	4,614.55	4,100.91	5,274.77	7,229.82	4,746.32	6,667.76	49,320
7. Total CO2 Reduction (k t-CO_2)	24,225.37	16,685.06	20,272.01	16,920.02	15,036.67	19,340.82	26,509.34	17,403.17	24,448.45	180,841
8. Total SO2 Reduction (k t-SO_2)	246.22	169.58	206.04	8,275.76	152.83	196.58	269.43	176.88	15,662.64	25,356
9. Total TSP Reduction (k t-TSP)	499.96	528.53	475.36	413.79	197.95	334.18	720.99	438.20	941.14	4,550
10. Consumer IRR	31.76	26.26	24.02	22.04	28.15	26.53	29.67	25.53	18.54	
11. Consumer Payback Period Without Project (years)	7.75	5.91	5.96	4.95	7.87	5.73	4.71	8.71	5.30	
12. Consumer Payback Period With Project (years)	7.13	5.72	5.78	4.94	7.15	5.57	4.60	7.77	5.30	
13. Boiler Producers IRR Without GEF Grant	6.73%	6.79%	6.18%	5.89%	5.70%	6.29%	6.15%	6.53%	5.97%	6.23%
14. Boiler Producers IRR With GEF Grant	11.59%	10.98%	12.76%	11.31%	11.59%	11.31%	12.31%	12.76%	13.15%	12.01%

Case 1: Packaged Water Tube Boiler (6 t/h)
Case 2: Improved Packaged Fireube-Watertube Boiler (6 t/h)
Case 3: Modular Water Tube Boiler Burning Low Sulfur Coal (10 t/h)
Case 4: Modular Water Tube Boiler Burning High Sulfur Coal (10 t/h)
Case 5: Packaged & Modular Hot Water Boiler With Water Tube (10 t/h)
Case 6: packaged & Modular Extended Furnace Water & Fired Tube Boiler (6 t/h)
Case 7: Medium Capacity Steam Boiler (75 t/h)
Case 8: Medium Capacity Hot Water Boiler (40 t/h)
Case 9: FBC Boiler (75 t/h)

NOTE: 1995 Exchange rate = 8.5 Yuan per US dollar.

TABLE 3
CHINA: EFFICIENT INDUSTRIAL BOILERS PROJECT
AVOIDED CO_2 EMISSIONS

	year	2000	2005	2010	2016
New and Replacement Boiler Demand ['000 tons (steam) per hour, ktph]		100-125	115-140	130-160	150-185
Improved Boiler Supply With Project (ktph)	annual cumulative	17 17	27 162	27 297	27 432
Direct Project Coal Savings [million tons raw coal (Mt)]	annual cumulative	0 0	5 13	8 47	12 102
Indirect Programmatic Coal Savings (Mt)	annual cumulative	1-2 1-2	7-15 26-51	15-30 59-117	39-65 230-416
Total Coal Savings (Mt)	annual cumulative	0 0	6-10 14-23	20-35 84-142	47-73 295-481
Direct Project CO_2 Reductions [million tons CO_2, (Mt CO_2)]	annual cumulative	0 0	8 23	15 84	21 181
Indirect CO_2 Reductions (Mt CO_2)	annual cumulative	0 0	7-15 16-33	30-60 117-231	78-128 456-824
Total CO_2 Reductions (Mt CO_2)	annual cumulative	0 0	15-23 39-56	45-75 201-315	99-149 637-1,005
GEF Cost Per Ton CO_2 (\$/tCO_2)	Direct Project Cost \$0.19		Total \$0.03-0.05		

ANNEX 10: BOILER MARKET ANALYSIS

1. At the end of 1995, there were approximately a half million industrial boilers in use in China with an installed thermal capacity of 1,198 thousand tons of steam per hour (Ktph). There are two dominant types of industrial boilers: ***steam boilers***, used for industrial process heat, in-plant electricity generation, and a combination of the two (cogeneration), and; ***hot water boilers***, used for low-temperature process heat for industry and for space heating for residential and commercial buildings (see Table 1). At the end of 1995, installed capacity of steam boilers in China was 806 Ktph, accounting for about two-thirds of total industrial boilers capacity, while hot water boilers reached 392 Ktph, accounting for the remaining one-third. For comparison, the energy output produced by industrial boilers (steam-tons) in China is about double that of power boilers, while the installed capacity is about 2.4 times as large.

TABLE 1: INSTALLED CAPACITY OF INDUSTRIAL BOILERS IN CHINA

	Total Capacity (Ktph)	Sets	Average Capacity (tph/set)	Steam (Ktph)	Steam %	Hot Water (Ktph)	Hot Water %
1978	373	200,000	1.86	--	--	--	--
1983	470	280,000	1.68	--	--	--	--
1988	857	369,286	2.31	--	--	--	--
1989	892	384,425	2.32	--	--	--	--
1990	944	410,697	2.30	--	--	--	--
1991	983	432,101	2.28	703	71.5	281	28.5
1992	1,028	442,578	2.32	718	69.8	310	30.2
1993	1,081	464,114	2.33	743	68.7	338	31.3
1994	1,100	--	--	738	67.1	362	32.9
1995	1,198	--	--	806	67.3	392	32.7

2. **The dominance of coal.** At present, more than 95 percent of China's industrial boiler capacity is coal-fired. Given the predominance of coal of China's proven energy resources, coal will remain the dominant fuel for industrial boilers for the foreseeable future. Depending on the development of domestic oil and gas resources, and given more

stringent environmental standards, the number of oil- and gas-fired industrial boilers will probably increase marginally in the future.

3. **Small sizes.** Although the average size of industrial boilers has increased in recent years, industrial boilers in China are still very small relative to international norms. In 1993, average boiler capacity was 2.33 tph, up from 1.86 tph in 1978. A survey of 13,930 industrial boilers in Beijing conducted in the late 1980s found that 78 percent of the boilers were less than 6 tph, including 65 percent 2-4 tph, 13 percent less than 1 tph, and 22 percent greater than 6 tph. By 1994, 67 percent of industrial boilers sold had a capacity of less than 6 tph, 24 percent were between 10-20 tph, and nine percent were above 35 tph. Among hot water boilers, the trend has been towards larger sizes, with the share of medium capacity (>10 tph) boilers increasing from 2.2 percent of the market in 1988 to 12.8 percent in 1994.

4. As seen in Table 1, the capacity of industrial boilers has grown significantly since 1978, closely paralleling the growth of the Chinese economy. One aspect of industrial boiler demand has been the increasing need for heat and power by small and medium-sized industries. A second important trend since the mid-1980s has been increased demand for space heating, concentrated in China's northern provinces. Industrial boilers have provided space heating for individual apartment buildings, district residential areas (district heating), and commercial buildings. Three areas of the country-North, Northeast, and East[15]-accounted for 70.3 percent of total installed capacity (tph) in China in 1993. In addition, eight provinces-Liaoning, Heilongjiang, Shandong, Hebei, Shanxi, Beijing, Jilin, and Jiangsu-accounted for 55 percent of total industrial boiler capacity in 1993. The combination of economic growth and space heating demand explains the dominance of industrial boilers in these regions and provinces.

5. Overall, the demand for industrial boilers in China has been strong since the early 1980s. However, there have been rather large variations in annual demand due to: (i) the removal of the industrial boiler industry from central planning, (ii) fluctuations in the economy, especially the rate of growth of TVEs and private enterprises, and (iii) changes in government credit, investment, and energy conservation policies. Between 1983 and 1995, the average demand for industrial boilers was 61 Ktph, with a low of only 19 Ktph in 1994, followed by a high of 98 Ktph in 1995. Data gathering and reporting inconsistencies may explain part of the variability. In addition to new demand, approximately 100 Ktph of small-scale boiler capacity was designated as low-efficiency during the 1980s and was required to be replaced or retrofit under the State Economic Commission's energy conservation system.

6. **Boiler production.** Industrial boiler production in China is characterized by generally low-technology and below-scale production levels, many small boiler

15 **North** China (Huabei) includes Hebei and Shanxi provinces, Inner Mongolia autonomous region, and Beijing municipality. **Northeast** China (Dongbei) includes Heilongjiang, Jilin, and Liaoning provinces. **East** China (Huadong) includes Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, and Shandong provinces.

producers, and an increasingly competitive market for both demand and supply. Some of the better boiler makers have gained market share over the past decade, due to products superior in performance, safety, and environmental controls. The thermal efficiency of boilers produced by the leading industrial boiler manufacturers is in the range of 70 percent; a great improvement over the 60-65 percent average for the industry as a whole, but still significantly below the 80+ percent efficiency levels achieved in many developed countries.

7. Boilers in China are classified in five grades-A-E-based upon the temperature and pressure under which the boiler vessels operate. There are 10 boiler works in China with A-grade licenses, manufacturing mostly large-scale power boilers, with the highest pressures and temperatures. Industrial boiler production by A-grade boilers works is minimal. There are also 10 B-grade boiler works in China, which manufacture both power boilers and industrial boilers. The B-grade boiler works mainly produce combined heat and power (CHP) boilers above 10 tph, and large-capacity hot water boilers. There are 27 boiler works with C-grade licenses and 153 boiler works with D-grade licenses. Both C- and D-grade boiler works produce steam and hot water boilers with low to medium pressure capabilities. There are a further 353 E-grade boiler manufacturers which produce very small, low-pressure, and low-temperature boilers; three-quarters of the output of E-grade boiler works are hot-water boilers. Among the 548 boiler producers in China (some boiler producers have more than one license), the number that produced more than 1,000 tph was only 33 in 1988, and only 16 in 1991. The number of plants with yearly output between 500-1,000 tph was 21 in 1988 and 25 in 1991.

TABLE 2: INDUSTRIAL BOILER PRODUCTION IN CHINA

	Total, of which:	Steam Boiler		Hot Water Boiler	
	(tph)	(tph)	%	(tph)	%
1985	88,237	--	--	--	--
1986	87,005	--	--	--	--
1987	85,483	--	--	--	--
1988	89,940	73,841	82.1	16,099	17.9
1989	84,875	66,712	78.6	18,163	21.4
1990	55,220	39,427	71.3	15,793	28.6
1991	66,462	47,986	72.2	18,476	27.8
1992	90,020	69,135	76.8	20,885	23.2
1993	99,734	76,596	76.8	23,138	23.2
1994	93,619	63,099	67.4	30,520	32.6
1995	99,423	--	--	--	--

Market Trends

8. From 1982 to 1991, the total output of industrial boilers was around 320,000 sets, with a thermal capacity of more than 750 Ktph. Since 1991, an additional 215 Ktph of new boiler capacity has been installed in China. The future trend in the demand for industrial boilers will be driven by the growth of light and textile industries, township and village industries (TVEs), and an increase in the area of space heating in northern China.

9. **Industrial demand.** The key industries that have driven the demand for industrial boilers since 1980 have been the light and textile, energy, metallurgy, and building material industries.

(a) The light and textile industry has accounted for about 20 percent of industrial boiler demand over the past decade, and this sector is expected to continue to provide a strong demand. In addition to the textile industry, which grew above 10 percent per year during most of the 1980s, other light industries that use industrial boilers are pulp and paper, refined sugar, and synthetic detergents. Cogeneration and hot water boilers will increasingly be needed for the printing, dyeing, and knitting industries.

(b) The petrochemical industry has been an important user of industrial boilers, accounting for about 15 percent of total demand. Among the processes that require industrial boilers are: synthetic ammonia, ethylene, rubber, and caustic soda. The petrochemical industry is expected to grow at approximately 10 percent per year over the coming decade. Future demand by the petrochemical industry will be for waste-heat recovery, auxiliary, and cogeneration industrial boilers.

(c) The metallurgical industry has accounted for about five percent of industrial boiler demand over the past decade, and, the production of ferrous and nonferrous metals is expected to grow especially rapidly over the coming decade. Cogeneration and heat recovery boilers will be the dominant products demanded.

(d) Within the building material industry, cement manufacturing has been the dominant user of industrial boilers, primarily waste-heat and cogeneration boilers. Other industries in the sector driving the demand for boilers include glass, asbestos, and cement products. The building material industry is expected to grow at 12 to 14 percent over the coming decade and, the demand for cogeneration boilers is expected to double by the year 2000. This trend is reflected in the share of 20-130 tph steam boilers that can be used for cogeneration, which increased from 15.8 percent in 1988 to 26 percent in 1993.

10. **Space heating.** The share of hot water boilers has been increasing steadily since 1980 due to the gradual decontrol of the urban housing market, rising incomes, and

increased demand for larger scale heat generation due to scale economies and government policy. The central heating area in urban areas in northern China increased from 11.3 million m^2 in 1980 to 189.8 million m^2 in 1990. For the country as a whole, the percentage of the urban population with central heating was raised from 2.0 percent in 1980 to 12.1 percent in 1990. The share of hot water boilers to total industrial boilers grew from around 18 percent in 1988 to 33 percent in 1995.

11. Central and local governments have been promoting the use of central and district heating and cogeneration in urban areas as an alternative to individual stoves for residential heating for both energy efficiency and pollution reduction reasons. Harbin, in Heilongjiang Province, which has an extremely cold climate, expects that the residential living area that is heated will rise from 10.5 percent in 1985 to some 77 percent by the year 2000. According to central government plans, city central heating areas will increase from 0.19 billion m^2 in 1990 to 5.4 billion m^2 in 2000, bringing the total urban population with central heating to 40 to 50 percent.

12. **Environmental concerns.** Many municipalities in China have enacted stricter environmental regulations in recent years in response to severe and deteriorating air quality. Coal combustion by industrial boilers and small residential stoves is often cited as the dominant source of both TSP and SO_2 pollution in Chinese cities, and studies in a wide variety of cities across the country have confirmed this hypothesis. Policy at both the national and local levels have been directed at reducing the emissions from residential stoves and industrial boilers, including: (i) limiting the allowable sulfur and ash content of the coal supplied to particular regions, (ii) promoting, through subsidies and public investments, the use of coal briquettes for reducing fly ash and sulfur, (iii) increasing the supply of LPG, natural gas, and town gas for residential uses, and (iv) investing in fluidized bed combustion (FBC) boilers for limiting sulfur emissions. The share of FBC boilers in China increased from 4.6 percent in 1988 to 7.5 percent in 1993. Anecdotal evidence shows that the number of new orders for FBCs has been growing rapidly throughout the country over the past five years, particularly in tourist towns and in cities with severe sulfur pollution problems.

Forecasts of Industrial Boiler Demand

13. Based on the demand trends for new and replacement boilers, forecasts of future boiler demand in China to the year 2010 have been estimated under various assumptions. The original forecasts prepared by the joint Chinese-international expert group,[16] have been augmented by MMI in light of the most recent market information. Assuming an economic growth rate of 6-8 percent over the coming 15 years, industrial boiler demand (tph) is conservatively estimated to increase between two and three percent per year to the year 2010.

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16 *Prefeasibility Study on High Efficiency Industrial Boilers*, Subreport 11, *China: Issues and Options in Greenhouse Gas Emissions Control*, August 1994.

14. **Replacement boilers.** The current service life of Chinese industrial boilers is about 15 years, however, this period is expected to rise to 20 years or more in the future due to the development of water tube boilers and to the improvement in manufacturing quality. By the year 2010, most of the current stock of industrial boilers is expected to be replaced, with an average of about 54,000 boilers replaced each year.

15. Despite the virtual lack of coal-fired industrial boilers in other industrial countries, the demand for these boilers in China is expected to continue and even grow over the coming twenty years. The Chinese Ministry of Machinery Industry estimates that the annual demand for industrial boilers-both new and replacement-is currently 85-100 thousand tons of steam per hour (ktph), and will rise to 100-125 ktph by 2000, and to 130-160 ktph by 2010.[17] Cumulative production of new and replacement boilers over the next twenty years would be in the range of 2.1 to 2.6 million tph.

Expected Market Penetration of Project Boilers

16. Industrial boilers are typically classified according to their use, structural characteristics, combustion method, and fuel type. There are currently 13 types of industrial boilers in China based on these factors. The five boiler types shown in Table 3, which are the boiler types that will be produced under the GEF Efficient Industrial Boilers Project, presently account for about 70 percent of the total boiler market in China. Although hot water and FBC boilers do not occupy a large portion of the market at present, the demand for space heating and cleaner industrial boilers will lead to increased demand for these boilers in the future.

TABLE 3: BOILER PRODUCTION BY MODEL TYPE

	1988		1994	
	(tph)	%	(tph)	%
Total Production	**89,940**	**100.0**	**93,619**	**100.0**
1. Packaged water steam	4,677	5.2	8,492	9.1
2. Packaged water-fire tube	42,281	47.0	33,356	35.6
3. Modulated water tube steam	1,961	2.2	9,025	9.6
4. Packaged modulated water tube hot water	1,727	1.9	11,028	11.8
5. Fluidized bed combustion (FBC)	2,788	3.1	2,793	2.8

17. Total boiler production by the nine project enterprises is planned to reach 27,000 tph of annual production capacity by the year 2002, accounting for about one-

17 *Prefeasibility Study on High Efficiency Industrial Boilers*, China Greenhouse Gas Study, Subreport No. 11, August 1994.

quarter of national industrial boiler production. Two scenarios-low and high-for the dissemination of the new boiler models to other boiler producers were developed to estimate the potential market penetration of the improved boilers. These scenarios, presented in Annex 9, Table 3, show that the indirect project benefits of extending the higher-efficiency boiler designs to other manufacturers is likely to extend to 50 to 70 percent of the industrial boiler market within 15 to 20 years.

Boiler Price Analysis

18. Boiler prices used in the cost-benefit (Annex 5) and incremental cost (Annex 6) analyses were determined based on: (i) a recent market price survey of industrial boilers carried out by MMI, and (ii) a cost-benefit analysis for boiler producers and consumers of manufacturing and purchasing the new boilers.

19. **Price survey.** Sales prices of industrial boilers in China since 1985 have been evaluated. Prior to the mid-1980s, industrial boilers prices, like most industrial products, were determined through central planning agencies with little differentiation due to quality or other characteristics. This situation has changed considerably in the industrial boiler industry, which is now largely market driven. As can be seen in Table 4, there is presently a wide range of prices for the same size and type of boiler, with the price differential due to energy efficiency, safety, reliability, pollution control, or name recognition. For instance, for a 4 tph industrial boiler, the variation of prices around the mean was +15 and -19 percent. For a 10 tph boiler, the variation around the mean was +36 and -24 percent.

TABLE 4: PRICE SURVEY OF INDUSTRIAL BOILERS

	4 tph		6 tph		10 tph	
Enterprise	10^3 Yuan	variation around mean (%)	10^3 Yuan	variation around mean (%)	10^3 Yuan	variation around mean (%)
1	177	-3	293	+7	524	+13
2	187	+2	280	+2	462	--
3	200	+9	302	+10	509	+10
4	182	-1	310	+13	442	-4
5	186	+2	220	-20	480	+4
6	200	+9	240	-12	410	-11
7	175	-4			385	-17
8	192	+5			420	-9
9	210	+15			470	+2
10	158	-14			628	+36
11	148	-19			350	-24
Ave.	**183**		**274**		**462**	
($)	**$21,529**		**$32,235**		**$54,353**	

20. **Cost-benefit analysis.** The maximum price that consumers would be willing to pay for the new boiler was determined with reference to the rate of return and payback period. All other things equal, it was assumed that consumers would be unwilling to purchase the new boiler unless the financial rate of return was at least as high as with the older model boiler. Similarly, it was assumed that the payback period for the investment in the new boiler could be no longer than for the old model. The financial benefits to consumers of purchasing the new boiler are primarily the lower fuel operating costs due to the improvement in operational thermal efficiency. A *maximum* price for boiler consumers was defined and calculated as the price that would extract all consumer surplus; i.e., the price of the new boiler is so high that there are no financial benefits to the new boiler compared to the older model, or, equivalently, the price at which the internal rate of return of the "with" and "without" project cases are equal. In reality, it is unrealistic to assume that a new boiler model, unfamiliar to customers, will be able to gain market share if the sales price is so high that there are no financial benefits to consumers. For this reason, the price cannot be raised too high, and there is the need for the other benefits of the new boilers to be provided to consumers. For the producer, a *minimum* price of the new boiler was calculated as the price necessary for the boiler manufacturer to earn a project internal financial rate of return of 12 percent. The consumer maximum and producer minimum price are shown in Table 5, along with the current average market price of existing comparable (less efficient) boilers, and the estimated market price of the new boilers used in the financial/economic and incremental cost analyses.

TABLE 5: BOILER PRICE DETERMINATION

Subproject	Current Average Market Price (1000 Y)	Consumer Maximum Price /a	Producer Minimum Price /a	Estimated Market Price of Improved GEF Boiler /a
1	294	26.0%	21.4%	16.5%
2	260	26.0%	22.3%	17.0%
3	540	18.5%	17.8%	13.5%
4	460	20.0%	21.2%	17.0%
5	480	33.0%	19.3%	14.5%
6	294	22.4%	22.3%	17.0%
7	4200	22.9%	26.0%	19.5%
8	1810	35.0%	23.5%	16.5%
9	4600	15.0%	20.0%	13.5%

/a: Calculated as the percentage increase above the current market average for the given boiler model.

ANNEX 11: SUPERVISION PLAN

Proposed Date	Activities	Expected Skill Requirement	Staff Input (SW)
03/97	Project Launch Mission to initiate project implementaton, review procurement progress of the project, ensure institutional arrangements are in place, and commence pilot dissemination programs	Procurement Specialist, Boiler Specialist, Financial Analyst, Economist	13
09/97	Supervision Mission to review Phase 1 implementation, institutional development and status of technical assistance implementation	Procurement Specialist, Boiler Specialist, Economist	10
03/98	Technical Review Mission to review the technical performance of the model boiler and evaluate enterprises on criteria which will allow them to proceed to Phase 2 of project implementation	Boiler Specialist, Financial Analyst, Economist	10
09/98	Supervision Mission tot review progress of project implementation and status of TA	Boiler Specialist, Financial Analyst, Economist	9
1999-2000	At least one supervision mission a year and last mission should discuss with MMI the preparation of ICR	To be determined depending on progress made	—

Note: Ongoing review of bidding/procurement documents in Washington will require additional SW inputs.

ANNEX 12: DETAILED PROJECT COST AND FINANCING

DETAILED PROJECT COST AND FINANCING-FIRST PHASE
($'000 or Y'000)

	1996		1997		1998		Subtotal	
	Local(Y)	Foreign ($)	Local(Y)	Foreign ($)	Local(Y)	Foreign ($)	Local(Y)	Foreign ($)
Project Cost:								
Upgrading of Existing Boilers								
Construction Engineering	0		0		0		0	0
Equipment-demonstration unit		0		880		0	0	880
Equipment-production of new boiler	0	0	19,660	206	19,660	225	39,320	431
Technology Transfer Licensing		0		5,290		3,785	0	9,075
Engineering Services		0		3,248		2,347	0	5,595
License		0		2,042		1,438	0	3,480
Installation							0	0
Others	0		0		0		0	0
Working Capital	0		1,770		0		1,770	0
Subtotal	0	0	21,430	6,376	19,660	4,010	41,090	10,386
Adoption of New Boiler Design							0	0
Construction Engineering	0		0		0		0	0
Equipment-demonstration unit		0		880			0	880
Equipment-production of new boiler	0	0	16,885	140	16,885	140	33,770	280
Technology Transfer Licensing		0		4,850		3,460	0	8,310
Engineering Services		0		2,870		2,002	0	4,872
License		0		1,980		1,458	0	3,438
Installation							0	0
Others			0		0		0	0
Working Capital	0		5,900		0		5,900	0
Subtotal	0	0	22,785	5,870	16,885	3,600	39,670	9,470
Technical Assistance								
Operator Training	0	0	250	50	250	50	500	100
Marketing/dissemination	0	0	0	45	1,000	200	1,000	245
Revision of Standards	0	0	500	100	500	100	1,000	200
Boiler Design & Implementation	0	0	300	90	300	75	600	165
Boiler House Standards Development			250	70	250	50	500	120
Subtotal	0	0	1,300	355	2,300	475	3,600	830
Monitoring and Evaluation								
Project Evaluation			250	80	250	80	500	160
Thermal Efficiency Monitoring			130	70	130	75	260	145
Emissions Monitoring			130	75	130	75	260	150
Safety Validation			130	75	130	75	260	150
Subtotal			640	300	640	305	1,280	605
Project Management			870	195	870	175	1,740	370
Subtotal	0	0	2,810	850	3,810	955	6,620	1,805
Physical Contingencies	0	0	3,655	1,225	3,654	761	7,309	1,986
Price Contingencies	0	0	4,897	407	7,798	426	12,695	833
Total Project Cost	0	0	55,577	14,728	51,807	9,752	107,384	24,480
Interest During Construction	0		0		2,673		2,673	0
Total Financing Required	0	0	55,577	14,728	54,480	9,752	110,057	24,480
Sources of Financing:								
GEF Grant		0		14,728		9,752		24,480
Local Bank Loan	0		32,816		37,319		70,135	0
Working Capital Loan	0		5,369		0		5,369	0
Self-raised Fund	0		17,392		17,161		34,553	0
Total Sources of Fund	0	0	55,577	14,728	54,480	9,752	110,057	24,480

DETAILED PROJECT COST AND FINANCING: SECOND PHASE
($'000 or Y'000)

	1988		1999		2000		Subtotal		Total (Phases I & II)	
	Local (Y)	Foreign ($)	Local (Y)	Foreign ($)	Local (Y)	Foreign ($)	Local (Y)	Foreign ($)	Local (Y)	Foreign ($)
Project Cost:										
Upgrading of Existing Boilers										
Construction Engineering	9,234	0	15,390		6,056		30,680	0	30,680	0
Equipment-demonstration unit		0		0		0	0	0	0	880
Equipment-production of new boiler	11,996	1,864	20,160	2,069	8,264	0	40,420	3,933	79,740	4,364
Technology Transfer Licensing		0		0		0	0	0	0	9,075
Engineering Services		0		0		0	0	0	0	5,595
License		0		0		0	0	0	0	3,480
Installation							0	0	0	0
Others	1,488		3,384		1,896		6,768		6,768	0
Working Capital	29,356	0	52,857		43,187		125,400	0	127,170	0
Subtotal	52,074	1,864	91,791	2,069	59,403	0	203,268	3,933	244,358	14,319
Adoption of New Boiler Design										
Construction Engineering	6,506	0	10,810		4,304		21,620	0	21,620	0
Equipment-demonstration unit		0		0		0	0	0	0	880
Equipment-production of new boiler	10,776	1,260	17,360	1,260	7,284	0	35,420	2,520	69,190	2,800
Technology Transfer Licensing		0		0		0		0		8,310
Engineering Services		0		0		0		0		4,872
License		0		0		0		0		3,438
Installation		0		0		0		0		0
Others	589		1,474		884		2,947		2,947	
Working Capital	13,152	0	43,078		48,167		104,397	0	110,297	0
Subtotal	31,023	1,260	72,722	1,260	60,639	0	164,384	2,520	204,054	11,990
Technical Assistance										
Operator Training			400	67	400	67	800	134	1,300	234
Marketing/dissemination	0	0	400	75	400	75	800	150	1,800	395
Revision of Standards	0	0	400	75	400	0	800	75	1,800	275
Boiler Design & Implementation	0	0	100	20	100	15	200	35	800	200
Boiler House Standards Development			300	40	200	35	500	75	1,000	195
Subtotal	0	0	1,600	277	1,500	192	3,100	469	6,700	1,299
Monitoring and Evaluation										
Project Evaluation			400	42	400	20	800	62	1,300	222
Thermal Efficiency Monitoring			500	50	500	27	1,000	77	1,260	222
Emissions Monitoring			300	7	300	0	600	7	860	157
Safety Validation			300	25	300	25	600	50	860	200
Subtotal	0	0	1,500	124	1,500	72	3,000	196	4,280	801
Project Management			440	75	440	55	880	130	2,620	500
Subtotal	0	0	3,540	476	3,440	319	6,980	795	13,600	2,600
Physical Contingencies	4,059	312	6,858	333	2,869	0	13,786	645	21,095	2,631
Price Contingencies	8,661	175	20,042	264	10,794	0	39,497	439	52,192	1,272
Total Project Cost	95,817	3,611	194,953	4,402	137,145	319	427,915	8,332	535,299	32,812
Interest During Construction	2,675		16,767		25,370		44,812		47,485	
Total Financing Required	98,492	3,611	211,720	4,402	162,515	319	472,727	8,332	582,784	32,812
Sources of Financing:										
GEF Grant		3,611		4,402		319		8,332		32,812
Local Bank Loan	39,189		79,313		48,745		167,247		237,382	
Working Capital Loan	29,756		67,155		63,948		160,859	0	166,228	0
Self-raised Fund	29,548		65,253		49,822		144,623	0	179,176	0
Total Sources of Fund	98,493	3,611	211,721	4,402	162,515	319	472,729	8,332	582,786	32,812
US Dollar equivalent (Y8.5/$)	11,587	3,611	24,908	4,402	19,119	319	55,615	8,332	68,563	32,812
Total project cost in $ equivalent										101,375

ANNEX 13: TECHNICAL ASSISTANCE

1. Training and institutional support is being provided under the project to ensure that the advanced boiler technologies are disseminated throughout China and that other major factors affecting the thermal efficiency of Chinese industrial boilers are addressed. The following technical assistance programs are planned:

Boiler Operator Training and Certification Program

2. Previous studies have established that energy efficiency and pollution control from Chinese industrial boilers can be greatly improved by improving the operation of industrial boilers. This technical assistance program would seek to improve the skills of industrial boilers operators through advanced training and to initiate the necessary steps for establishing a boilers operation certification program in China. Boiler operation would be improved through: (a) the upgrading of boiler operator training, and (b) the design and establishment of a boiler certification program.

(a) **Boiler Operator Training**. This component would seek to: (i) Improve the quality of boiler operation in China, including the educational level, technical training, and system of rewards for boiler operators; (ii) The primary institutions responsible for training boiler operators in China would be identified, including technical schools, boiler manufacturers, or local government departments; (iii) Establish and initiate a long-term program of training workshops throughout the country, involving both trainers and trainees. Both international and domestic consultants would be involved in carrying out items (i) - (iii).

(b) **Certification Program**. A second component would seek to design a boiler operator certification program for China, drawing on the experiences of other countries where such programs exist, and on certification programs for other equipment operators in China. A leading group composed of institutions in China concerned with boiler operation (MMI, Ministry of Construction, Ministry of Labor, Ministry of Electric Power, insurance companies, trade associations) would be established to provide guidance in the design and implementation of the certification program. Design issues could include: basic requirements of prospective boiler operators, the content, extent, and duration of formal and apprenticeship training, and; in-service training and recertification.

Implementation issues could include: propaganda to demonstrate the benefits of the program to the industrial boiler industry (producers, users, regulators, insurance companies); institutional responsibilities and legal mechanisms for certification and enforcement.

Marketing and Dissemination

3. The success of the project is dependent on the sale of new high-efficiency boiler models, and on the dissemination of the technologies to other producers throughout China. This program will: (a) assist project enterprises in developing a marketing plan during Phase 1; (b) establish a pilot program at the local level for disseminating more efficient and cleaner industrial boilers, through the cooperation of central and local government environment and planning bureaus; (c) undertake a broad marketing campaign at the end of Phase 1, through national conferences supplemented by visits to the demonstration units; (d) assist other boiler producers in China to acquire the advanced boiler technologies demonstrated under the project.

(a) **Assistance to Project Enterprises**. At the end of the demonstration phase (Phase 1), the nine project enterprises must have a detailed and justifiable marketing plan in place before they may proceed with mass-production under Phase 2. This marketing plan would include the number of boilers to be produced, identification of prospective buyers (including letters of commitment), pricing of new boilers to maximize sales, and an advertising campaign. PMO would provide assistance to the project boiler enterprises, as requested, to ensure that a solid marketing plan is in place at the end of the demonstration phase.

(b) **Pilot Dissemination Program at the Local Level**. A pilot program would be established in three municipalities, including Beijing, Chongqing and Harbin, in collaboration with national-level environment and planning agencies. The intent of the pilot programs would be to stimulate the demand for more efficient and cleaner industrial boilers in municipalities with severe environmental problems. Local government agencies would be assisted in:

- Investigating the feasibility (including costs) of enforcing environmental standards for industrial boilers;
- Estimating the environmental and financial benefits of adopting specific GEF industrial boilers;
- Identifying prospective buyers of GEF boilers;
- Identifying incentives and penalties to enterprises and government agencies in adopting cleaner industrial boilers.

(c) **Customer Service**. After-sales service, currently a weak link in China's industrial boiler industry, would be strengthened under the project. Based on international experience in the industrial boiler industry and domestic experience in other industries, a best-practice program and action plan would be prepared and disseminated for providing customer service to industrial boiler consumers. Among the customer services that would be upgraded are: postinstallation assistance, long-term performance guarantees, preventive maintenance, technical upgrades, and operator training.

(d) **Nationwide Marketing Campaign**. At the end of Phase 1, a broad-based and well-designed advertising campaign would be initiated for marketing the GEF boilers. In addition to advertising, the campaign would include the holding of conferences and workshops for industrial boiler producers, users, regulators, insurance companies, and professional associations.

(e) **Technology Dissemination to Other Boiler Producers**. Following the successful demonstration of the GEF boilers, the technologies would be disseminated to other boiler producers in China, beginning with the enterprises identified during the feasibility stage of project preparation, and then extension to other qualified enterprises. Among the dissemination assistance provided to other boiler producers would be: (i) provision of information, including technical performance and financial advantages, of applicable boiler technologies, (ii) site visits to demonstration units, and technical/financial discussions with domestic and international boiler experts, (iii) training of enterprise personnel in the sale and after-sales service for the GEF boiler models, and (iv) introductions and arrangements for potential domestic and foreign equipment suppliers for product demonstrations and/or technical training.

Revision of Industrial Boilers Standards

4. In light of the improvements to be gained through technology transfer under the project, existing standards for industrial boilers and the related issue of fuel would be reviewed and new standards proposed. The principal standards that would be revised include: thermal efficiency, emissions (TSP, SO_2, NO_x), safety, and coal quality. While these standards are largely outside the authority of MMI to revise and enforce, the GEF project offers a unique opportunity for MMI to spearhead a review, and to make recommendations on the adoption and implementation of improved standards.

(a) **Review of Existing Standards**. Based on the technical performance of the GEF efficient industrial boilers, and drawing on advanced international experience, existing Chinese industrial boiler standards and norms would be reviewed. The review would focus on standards for thermal efficiency, pollution control, safety, and coal quality, but also cover norms for design, manufacturing, installation, commissioning, inspection, and monitoring and testing of industrial boilers.

(b) **Recommended New Standards.** In cooperation with the relevant institution in China responsible for establishing and enforcing thermal efficiency, pollution control, safety, and coal quality standards for industrial boilers, appropriate new standards would be recommended. Changes in norms for design, manufacturing and other aspects under the control of MMI would be acted upon directly by MMI.

(c) **Implementation of New Standards and Norms.** A schedule for phasing-in the recommended new standards would be agreed upon with the relevant agencies. The dissemination of new standards would be first applied to all boilers produced under the GEF project, followed by requirements applying to all new industrial boiler installations, and finally to all industrial boilers in the country. For the norms under the authority of MMI, the establishment and implementation of the revised norms would begin immediately.

Boiler Design Implementation Program

5. Because the GEF project will not cover the entire range of possible boiler sizes and pressure ranges, it is important to identify the specific design improvements that result in increases in thermal efficiency and to make these available to other boiler types. A Chinese design institute, assisted by international boiler design experts, would evaluate the design improvements embodied in the technology transfer for the project, and help to extend those design improvements to the entire range of boiler models in China and to make this information available to all boiler manufacturers in the country.

(a) **Product Design Analysis.** The design improvements identified in the course of the GEF project that are available through routine commercial transactions, or can be accomplished through the use of technology that is in the public domain, will be identified and made available to all Chinese industrial boiler firms. Among the areas to be evaluated are design procedures, computer programs, the selection/compatibility of auxiliary equipment and accessories, and the demonstration and verification testing of prototypes.

(b) **Product Design Extension.** Design improvements identified as part of (a) would be incorporated into design manuals and software for other industrial boiler products that are expected to have broad market coverage in the future. This information would then be made available to the industrial boiler industry through the key industrial boiler design institutes.

Boiler House Standards Development

6. The design technology for integrated industrial boiler houses in China is rather obsolete, which has a direct effect on both energy use and pollutant emissions of coal-fired boilers. The nine demonstration boiler houses of the GEF project will be used as guides in helping to improve overall boiler auxiliary equipment design in China. This work will involve investigation of practices in developed countries and the preparation of design methods, computer programs, and other engineering documents to be made available throughout the Chinese industrial boiler industry.

(a) **Boiler House Standards Development**. Standards will be developed to improve the practice of designing industrial boiler auxiliaries to bring them up to international standards, especially those standards which increase the thermal efficiency of coal-fired industrial boilers. MMI would ensure that the new standards are disseminated and followed throughout the country.

(b) **Development of Improved Integrated Technology**. Based on the international engineering practices used in the nine demonstration units, boiler technology and equipment for the overall boiler island system (including coal pretreatment, ash handling, flue gas cleaning, and control and monitoring) will be investigated and evaluated with the intention of raising the thermal efficiency and reducing the pollution levels of the integrated boiler house.

TABLE 1: BUDGET FOR TECHNICAL ASSISTANCE
($'000)

			Implementation Schedule
Boiler Operator Training and Certification Program:		**234**	Jul 97 - Jun 99
Domestic consultants:	9 person-months	45	
International consultant:	5 person-weeks	35	
Investigation abroad:	5 person. 3 weeks	30	
Training costs:		84	
Equipment (instrumentation and meters for training):		40	
Marketing and Dissemination:		**395**	May 97 - Jun 99
Domestic consultants:	30 person-months	150	
International consultant:	5 person-weeks	35	
Advertising and workshops:		120	
Training costs:		90	
Revision of Industrial Boiler Standards:		**275**	Jun 97 - Jan 99
Domestic consultants:	35 person-months	175	
International consultants:	10 person-weeks	70	
Investigation abroad:	5 persons, 3 weeks	30	
Boiler Design Implementation Program:		**200**	May 97 - Nov 98
Domestic consultants:	13 person-months	65	
International consultants:	10 person-weeks	70	
Investigation abroad:	5 persons, 3 weeks	30	
Computer equipment		35	
Boiler House Standards Development:		**190**	May 97 - Nov 98
Domestic consultants:	13 person-months	65	
International consultants:	10 person-weeks	70	
Investigation abroad:	5 persons, 3 weeks	30	
Computer equipment		50	
Total		**1,294**	

ANNEX 14: SELECTED DOCUMENTS AVAILABLE IN THE PROJECT FILE

1. Project Implementation Plan (PIP) (8/96)

2. Business licenses of the nine enterprises participating in the project (8/96)

3. Commitment letters from local banks for the counterpart funds for the nine subprojects(8/96)

4. Report on Preliminary Evaluation of the Feasibility Study (FS) on GEF Boiler Project (7/96), including:

   Annex 1: Evaluation Report of Chinese Enterprise Technical Qualification

   Annex 2: Financial Evaluation Report

   Annex 3: Evaluation Report of Technology Transfer and Project

5. Scores on the Final Selection of Participating Domestic Enterprises according to FSs (7/96)

6. Environment Analysis (7/96)

7. Market Survey (Chinese version, 7/96)

8. Financial Reports for all the Enterprises Participating in the Final Selection of their Feasibility Studies (6/96)

9. Feasibility Study - Terms of Reference (2/96)

10. Technology Transfer - Terms of Reference (2/96)

11. Forecast for GEF High Efficiency Industrial Boilers (12/95)

12. Visiting Report of International Technology Assessment (11/95)

13. Assessment Report of the Qualification for the International Enterprises and Selected Short List (12/95)

14. GEF Efficient Industrial Boiler Prefeasibility Study Report (11/95)

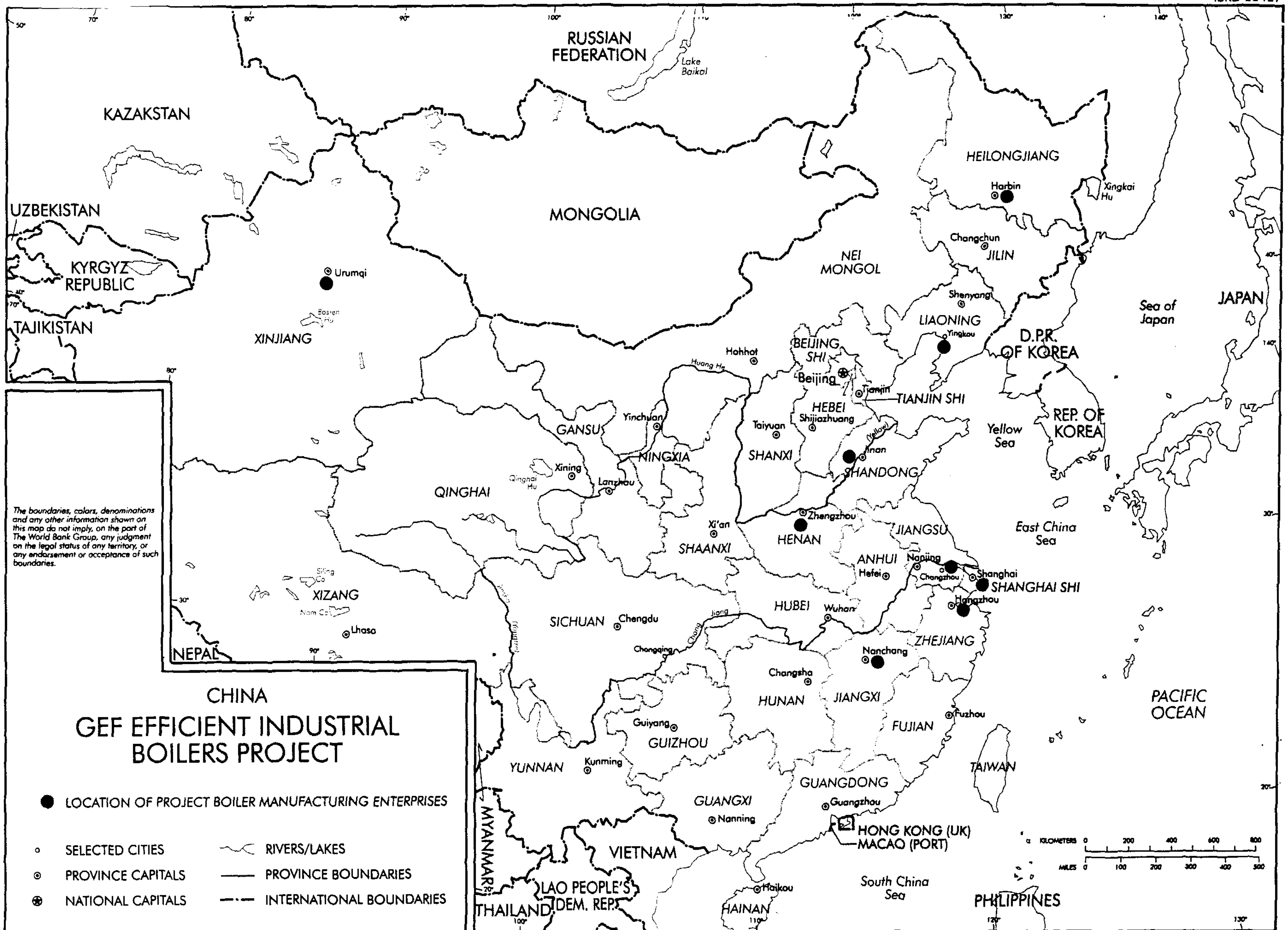
15. Financial Reports for the Prefeasibility Study (10/95)

16. Outline of Environmental Impact Assessment (1995)

17. Incremental Cost Analysis (Chinese version, 9/95)

18. Product Cost and Pricing Study (8/94)

IBRD 28427



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