ENERGY EFFICIENCY IN CHINA: TECHNICAL AND SECTORAL ANALYSIS

Report of a Joint Chinese-International Study Team

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Foreword

This report is one of eleven subreports prepared as inputs to the United Nations Development Programme (UNDP) technical assistance study, "China: Issues and Options in Greenhouse Gas Emissions Control," supported by the Global Environment Facility and executed by the Industry and Energy Division, China and Mongolia Deparment, of the World Bank. The views and opinions expressed in this report are those of the authors and do not necessarily represent the views of the World Bank.

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The report was edited by Barry G. Tunnah, together with Wang Shumao and Liu Feng. The following international and Chinese experts participated in the project preparing background sector reports, reviewing major trends, and selecting key energy efficiency projects for case study analysis (see subreport *Energy Efficiiency in China: Case Studies and Economic Analysis*).

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CURRENCY EQUIVALENTS

Official exchange rates:
Currency = RMB
Currency Unit = Yuan (Y)

1980: \$1 = Y 1.5
1990: \$1 = Y 4.7
1992: \$1 = Y 5.5

WEIGHTS AND MEASURES

gCE	=	10^6 TCE
kgCE	=	10^3 TCE
MTCW	=	10^6 TCE
MW	=	10^3 kW
TWh	=	10^9 kWh
kcal	=	4.19 kilojoules
TCE	=	7 x 10^6 kilocalories
ton standard coal	=	0.7143 TCE, average
TOE	=	1.43 TCE

ABBREVIATIONS AND ACRONYMS

BOF	-	Basic oxygen furnace
CO_2	-	Carbon dioxide
IRR	-	Internal rate of return
kGCE	-	Kilogram coal equivalent
kj	-	Kilojoule
kW	-	Kilowatt
kWh	-	Kilowatt-hour
m	-	meter
m^2	-	Cubic meters
MTCE	-	Million tons coal equivalent
MW	-	Megawatt
NH_3	-	Ammonia
NO_X	-	Oxides of nitrogen
SO_2	-	Sulfur dioxide
SPC	-	State Planning Commission
t	-	metric ton
TCE	-	Ton coal equivalent
TOE	-	Ton oil equivalent
tpy	-	tons per year
tsc	-	Ton standard coal
TSP	-	Total suspended particulates
TVE	-	Township and village enterprise
TWh	-	Terawatt-hour

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SUMMARY AND RECOMMENDATIONS

Background

i. China, as a major coal user, is a major source of greenhouse gas emissions. Although per capita energy consumption is relatively low—about one quarter of the world average and one tenth of typical developed country consumptions—the annual contribution of CO_2 is already 9 percent of the world total. It is estimated that 80 percent comes from the use of fossil fuels as energy sources. The rapid growth of the Chinese economy means that the emissions will also continue to increase rapidly unless vigorous efforts are made to improve energy efficiency.

ii. The basic objective of the study is the development of strategies for reducing greenhouse gas emissions, based on a comprehensive investigation of the current situation and projections for energy use and emissions over the next 15-20 years. The study includes a number of related elements through which the sources and sinks for greenhouse gases are characterized and options for modifying emissions are explored. This report—part of Output 1.2 of the study which addresses the potential for improvements in energy efficiency—summarizes the situation in major energy consuming sectors: industry, transport, agriculture, buildings, coal mining and electricity generation.

iii. The study was started in early 1992 with formulation of the terms of reference. A team was set up to collect data, to write sector Background Reports, and to participate in case study evaluations. The latter consisted of analyses of selected technologies with the potential to save energy and reduce greenhouse gas emissions, and with broad applicability in the various sectors. The Chinese counterparts were coordinated through the State Planning Commission (SPC) and team participants were drawn from a wide range of ministries and agencies. The Energy Research Institute of SPC also took part in most aspects of the work.

iv. The measures reported here for improving energy efficiencies address principally the short to medium term potential for energy savings. They mainly use well known technologies, proven in applications in China and other countries and likely to be applied in the 1990s and early years of the next century. In general, structural changes to industries and significant shifts to the type of product made in a sector are not included in this report, although it is recognized that such changes could eventually be much more significant than conventional "energy conservation measures." These important items are therefore addressed in a separate part of the study.

Data

v. The data collected in the study were obtained from a variety of sources. Internal data from various ministries and research institutes were used extensively, together with published national statistics. Although the sector Background Reports were written in somewhat different formats, this final report attempts to present information in a consistent format.

vi. For the most part, the data are reported for 1990 but some sectors have presented data for 1991. To the extent possible, inconsistencies in the data have been eliminated: some discrepancies always occur when so many different sources are involved, and central government statistics may differ from the corresponding figures of individual ministries. Also, forecasts of sector outputs and energy use have been given by most of the ministries but there has been no attempt here to ensure total consistency between the forecasts. This consistency has been achieved in other parts of the study by using input/output modelling techniques.

Energy Management and Conservation

vii. This report—and the Background Reports for sectors and subsectors from which it is derived—focuses principally on the short to medium term potential for energy savings. Measures already adopted, and most of those proposed, use proven equipment and processes. The typical measures are appropriate for the present time and are likely to continue to be applied for say 15-20 years in existing plants, and as part of the design of new facilities.

viii. Other changes that could have a profound effect on energy efficiency include the location of new processing plants, of an economic scale by international standards, near either raw material sources or markets. These plants would gradually replace existing subeconomic-scale facilities dispersed all over the country that are often far from both raw materials and energy sources, and distant from their markets. This topic is outside the scope of this report.

ix. All sectors report that energy efficiency has been improved over the last ten years or so in China. In addition, however, all report that more needs to be done and can be done, mostly using similar methods, equipment and processes as before. Most sectors recognize the role of good energy management but there is also a strong desire to see technical solutions to the problem of high energy consumptions. While it is undoubtedly true that new equipment and new processes are essential for continued medium to long term progress in reducing energy use and emissions of greenhouse gases, the contribution of good management and of more effective operation of existing facilities should not be underrated. Indeed, it is unlikely that the optimum benefits will be obtained from modern equipment and new technologies in the absence of strong energy management.

Case Studies

x. For each sector, technologies with good energy conservation potential and with the potential to reduce emissions of greenhouse gases and local pollutants were identified. These were reviewed and 24 were selected for detailed analysis. All the technologies had been applied at least once in China or were about to be implemented, and all had good prospects of replication in their respective sectors. Actual plant data were then collected on field visits around China.

xi. Returns on investment and payback periods were estimated for each technology application. Forecasts of "business as usual" (BAU) and "accelerated" (ACCEL) scenarios for adoption of each of the technologies or modifications were made. Both BAU and ACCEL scenarios were developed from information supplied in the Background Reports and by analogy with trends in the respective industries in other countries. Technical judgement was used to develop the respective scenarios, which were then used to calculate the forecasts of changes in energy consumption and emissions for 2000 and 2010.

xii. Most of the measures were found beneficial to the industry or plant concerned. Put simply, we can conclude that energy efficiency is usually very good business, and the reduced emissions of global warming gases that are achieved at the same time are an extra bonus.

xiii. The technologies analyzed as case studies are as follows:

Iron and Steel Industry

- M1 Open hearth converters replaced by BOF systems
- M2 Continuous casting
- M3 Reheat furnace renovation
- M4 BF gas recovery for steam/electricity generation

Nonferrous Metals

- M5 Aluminum plant renovation

Building Materials

- B1 Replace old dry kilns by preheater/precalciner systems
- B2 Wet to dry conversion
- B3 Vertical shaft kiln renovation

Paper

- L1 Black liquor recovery
- L2 Cogeneration in a paper mill

Textiles

- T1 Cogeneration in a textile mill
- T2 Caustic soda recovery
- T3 Computerized energy management systems

Chemicals

- CH1 Medium size ammonia plant renovation
- CH2 Small ammonia plant renovation and waste heat recovery
- CH3 New membrane process at NaOH plant

Equipment

- E1 High efficiency motors
- E2 Variable speed motors
- E3 Electric motor repair centers
- E4 Steam traps

Coal

- C1 Coal washing and screening
- C2 Coal briquetting

Electricity

- P1 Reduction of line losses in low voltage distribution systems
- P2 Technologies for improving power plant performance

xiv. For many of the technologies, the returns on investment and payback periods were found to be attractive. Particularly attractive were variable speed motor drives and improved steam traps, with good paybacks and the potential for widespread application in many industrial plants.

Barriers to Energy Efficiency Improvement

xv. The attractiveness of most of the case studies, and the fact that energy conservation has been seen in every sector to some extent at least, suggests that further gains in energy efficiency could be achieved by many firms for relatively low investments —or, where capital is needed, with excellent paybacks. However, the level of interest in energy conservation remains moderate, with many firms simply not taking advantage of the profitable opportunities available to them. This is by no means confined to Chinese firms: the same reluctance to invest in energy conservation is seen in many other countries.

xvi. Why therefore is energy conservation not exploited fully as a means to lower costs and higher profitability? Why is it necessary to promote energy efficiency and persuade firms to take action, when in fact energy conservation is in their own interests? There are various reasons, some or all of which will apply in any particular firm, such as:

(a) A concern to maximize production, with little or no interest in the cost or efficiency of production.

(b) No appreciation of the potential benefits of simple, low cost, energy saving measures.

(c) A belief that energy efficiency is a new and untried approach: conservative management often prefers to stay with old methods of working.

(c) A belief that energy conservation requires major funding and new investments and therefore is not applicable.

(d) A proper economic analysis has not been done (perhaps the firm lacks the skills to carry out economic analyses).

(e) There is a lack of technical skills in the firm to identify and evaluate energy saving opportunities.

(f) The firm lacks technical skills to design and install energy saving measures, and assistance is not available locally.

(g) There is a lack of appreciation of modern technologies available for their industry (lack of information).

xvii. Promoting energy efficiency therefore needs to address technical, economic and institutional barriers. This can be done through educating managers and decision makers in the benefits of conservation, training plant personnel in the appropriate analytical and engineering skills, and making cost effectiveness a cornerstone of decision-making in operating enterprises. At the policy level, government can provide the right environment for cost effective conservation by offering financial incentives to reward good energy management. Both policy measures and specific actions which could encourage energy efficiency are discussed further below.

Energy Efficiency Improvement in Specific Sectors

xviii. For each sector and subsector, there are areas where more effort needs to be placed to achieve continuing improvements in energy utilization and reduction or amelioration of pollutant emissions. Major sector or industry-specific items which would contribute to energy savings and lower emissions include the following:

(a) **Iron and Steel**

- Modernization of outdated furnaces and other equipment, and adoption of large-scale processing facilities in place of multiple units of a subeconomic scale.

- Phase out of highly inefficient and severely polluting equipment such as open hearth steel converters and poorly designed and maintained coking plants.

- Further adoption of the continuous casting process.

- Recovery of waste heat and waste gases from processing units for useful application within the same plant, at nearby plants, or for electricity generation for export to the grid.

(b) **Nonferrous Metals**

- Replacement of outdated copper, lead and zinc smelters by new facilities in suitable locations. Most existing plants are at least 25 years old.

- Renovation of large-scale existing facilities for the electrolytic refining of aluminum, and adoption of modern technologies for new plants.

(c) **Cement**

- Replacement of small old plants by large-scale modern plants with high energy efficiency and improved dust emission protection. There are over 5,000 small-scale plants, of which about 2,000 use primitive types of shaft kiln.

- Renovation or replacement of existing large- and medium-scale plants, half of which were built over 40 years ago. This will include replacement of wet process kilns where possible by preheater or precalciner systems.

- Utilization of industrial wastes such as fly ash and coal washery wastes as feed to cement kilns or for the production of blended cements should be encouraged. More blended cements should be produced to meet certain markets where their properties are fully acceptable or preferred (e.g., large-scale hydraulic dams and similar massive structures).

- Electricity generation by heat recovery in old kilns should be evaluated because the economic viability of this technique is suspect. All such plants have been shut down in western countries.

(d) **Flat Glass, Ceramic Tiles, Lime**

- As for much of the buildings material sector, old and outdated plants, many of them very small by world standards, need replacement by larger modern plants.

(e) **Clay Bricks**

- This sector is dominated by TVE plants, many of which are very small and use simple technologies. Plant size is increasing for new TVE plants, however, and there are process developments which result in good energy efficiency. TVE plants should therefore be encouraged to adopt the process developments that are already available when planning new facilities.

- The proportion of hollow or perforated bricks remains very low in China at about 0.3 percent of the total output. In many developed countries, the extent of perforated brick production is high. This type of brick requires less energy to make, consumes less raw material for a given construction volume, and has superior insulating properties in service.

(f) **Paper**

- Adoption of black liquor recovery in more paper plants for energy and caustic soda recovery, and increased utilization of waste materials such as bark, chips and sawdust.

- Increased use of cogeneration in the paper industry.

- Replacement of old small plants by larger modern facilities, in which black liquor recovery and cogeneration investments are more likely to be economic.

(g) **Textiles**

- Replacement of old small plants, as for most other sectors, and greater application of modern technologies and electronic controls.

(h) **Chemicals, Petrochemicals**

- Renovation or replacement of small and medium-scale ammonia plants, of which there are over 1,000 making ammonium bicarbonate. These were mostly built over 20 years ago and are inefficient by typical developed country standards and are too small to reach economic viability by normal evaluation criteria.

- Enterprise scale needs to be reviewed, as there are many small-scale plants which are uneconomic by normal standards and are unlikely to ever reach true commercial viability.

(i) **Equipment**

- Many items of equipment are not up to the standards of similar items on the international marketplace. Technology transfer through licensing agreements should be considered for key items such as certain types of electric motor, industrial scale boilers, steam traps, fans and pumps, controls and instrumentation.

(j) **Coal Mining**

- Old equipment and inefficient items such as ventilator fans and water pumps (and associated motors) need to be replaced by modern energy efficient designs.

- Coal washing and screening facilities are important in providing higher quality coals—and coals of a constant quality—to customers. This would allow higher levels of coal combustion efficiency to be achieved by most users, and sulphur emission levels would also be reduced by selective removal of sulphur compounds in the washing stage.

(k) **Power Sector**

- Old generating plants based on low or medium pressure boilers should continue to be replaced by modern, large, high pressure units.

- Electricity distribution systems need upgrading to take higher loads. Power factor compensation in distribution systems should be improved and many parts of the cable systems require renewal.

- All aspects of electricity distribution losses should be investigated and action taken to reduce losses in order of priorities. As suggested in item (2), certain equipment may need replacement, including transformers.

- Existing large power plants based on fossil fuels should be brought up to higher efficiency by using available technologies such as modern burners and improved heat recovery from combustion gases in water or air preheat systems, and by improving maintenance standards.

Policy Actions to Promote Energy Efficiency

xix. The actions needed to stimulate interest in energy efficiency and to achieve positive results are varied in nature. It is necessary firstly to create an environment in which energy efficiency is seen as a priority because it will bring benefits to the enterprise and the individual. These benefits may be seen in a variety of forms and combinations, such as through higher profitability and higher salaries or bonuses, through better working and safer conditions in the enterprise itself, and as a cleaner and more pleasant environment for living in the area surrounding the enterprise due to reduced local pollution. Secondly, the skills and tools needed to achieve practical energy saving must be provided at the enterprise level.

xx. Actions at a policy level could include a combination of measures such as the following:

(a) Focusing—in laws, regulations, and tax measures—on energy efficiency as a major contributor to the profitability of enterprises, to an improvement of the local environmental conditions, and to a reduction in global warming. This focus should be directed to improving the performance of existing plants and to ensuring that new plant design standards take account of energy efficiency.

(b) Maintaining pricing policies for fuels and electricity which reflect long run marginal costs and which reduce, or eliminate, subsidies for energy.

(c) Supporting training to improve energy awareness at a general level and to raise skills in economic analysis and energy related technologies for enterprise and government agencies at all levels, from national to local.

(d) Providing funding support to enterprises investing in energy efficient and low polluting processes, through financial incentives or in the form of loans and grants targeted to energy efficiency.

(e) Providing general industrial promotion policies which encourage modernization of energy intensive industries. Adoption of best modern practice in new plants, coupled with proper analysis to ensure appropriate plant scale and location, will make a significant contribution to energy saving and emission reduction.

(f) Encouraging wider application of indigenous technologies where appropriate. These may be more suitable for application in China than large-scale technologies used internationally because they are cheaper, use local materials and take account of local skills in making the equipment concerned and operating it. It is necessary to compare options carefully on a case by case basis, but some examples of effective Chinese technologies are:

- Brick-making kilns of the standard annular or hoffman type modified with heat recovery systems and utilizing waste gangue from coal washing plants.
- Modified and improved low polluting coke ovens capable of operating on a small scale (well below the economic efficient size of mechanized coke ovens).

(g) Enforcing more effectively the existing regulations for emission control. In addition, building of new plants should not be allowed in areas where air quality standards are not met unless existing plants reduce their discharges to accommodate the new discharge.

(h) Enforcing regulations for the phase out of inefficient products such as outdated electric motor designs. There is also a need to stop old and inefficient equipment long past its normal useful life being passed on to small collective-owned enterprises from plants undergoing modernization.

Specific Activities for the Short and Medium Term

xxi. To address some of the barriers to energy conservation quoted previously, there are a number of activities that could be undertaken at a practical level. There is, for example, a need to promote low cost simple measures to save energy and reduce emissions. The claim that there is no money for energy conservation is frequently made by enterprises, often as an excuse for inactivity. Indeed, the gains from simple low cost actions can often pay for the next stage of a conservation plan, the investment in new equipment and processes.

xxii. There is a need to promote the "efficiency ethic" in all energy consuming activities through proper management of energy and other resources. Thus, for example, wasteful consumption of raw materials should be reduced, especially materials such as steel and cement which have large amounts of energy embodied. This requires education to raise energy awareness, training in management practices and specific technologies, and training in the techniques of economic analysis for day-to-day decision making, both for enterprise personnel (operating and administrative) and for nonenterprise personnel such as staff of local government planning and economic bureaux and local development banks.

xxiii. It is appropriate to adopt a local level approach to energy conservation where possible. There is often more enthusiasm for local projects as the national level approach can seem distant and unrelated to local needs. Usually a more direct involvement can be stimulated locally because the results of energy saving—and particularly emission reduction—are experienced immediately at the local level. Municipalities are usually more motivated to achieve results than national agencies because they are faced with real local problems every day.

xxiv. Specific activities to raise awareness and skill levels can take a wide variety of forms. For example:

(a) Setting up demonstrations of energy efficient equipment and processes, from low cost/no cost items such as energy management systems, improved maintenance procedures, and instrumentation, to higher capital investment items such as new boilers, high efficiency electric motors, and heat recovery systems. Practical demonstrations in a Chinese context are important to convince enterprise managers of the technical and economic viability of "new" technologies, even though these may already have received broad acceptance internationally. Demonstrations should include publicity activities such as seminars and plant visits.

(b) Promoting a customer service approach by equipment suppliers through training in modern marketing methods, coupled with customer training to raise awareness of available alternatives and the need for economic analyses in equipment selection.

(c) Setting up specific demonstration and technical assistance programs to encourage the adoption of improved "generic" technologies. This may be done firstly by creating a better awareness in users of the capabilities of selected technologies through demonstrations and secondly by upgrading Chinese industries to supply the energy efficient products. For example, such programs could be set up for steam traps, variable speed electric motor devices, industrial boilers and associated controls, steam system insulation, and cogeneration applications. A program for steam traps could include assisting the manufacturers of traps with better designs, better manufacturing techniques and quality control, and the use of better materials of construction.

(d) Setting up local technical assistance centers—or raising the skill levels and equipment available in existing centers—to provide stronger support to local enterprises for economic and technical evaluations of both current operations and planned investments. Through local centers, developing the concept of monitoring and targeting at a practical level by applying the technique in local enterprises as a demonstration project.

(e) Training in local service centers should be considered in three basic categories:

- "Service orientation" for local service centers, planning and economic commissions, TVE bureaux and similar agencies.
- Technical, mainly for enterprise personnel, to include the role of economics in daily decision making, energy management principles, and the technical aspects of relevant processes.
- Investment appraisal and postinvestment monitoring for enterprise managers and financial officers, and for local development bank officials responsible for loans to firms.

(f) Undertaking specific programs to address problems identified in key sectors, for example:

  - A line loss reduction program for low voltage local electricity distribution systems.
  - A program to study systematically the availability and utilization of industrial wastes (e.g., cement and brick plant feedstock; synthetic construction materials).
  - A program to study manufacturing techniques and applications for perforated bricks.

(g) Initiating vigorous efforts to upgrade coal quality by washing, screening and briquetting, as this will have a beneficial effect on a wide range of users and allow them to improve the standard of their operations.

1. INTRODUCTION

A. BACKGROUND TO THE STUDY

1.1 China, as a major coal user, is a major contributor of greenhouse gas emissions. Although the energy consumption of China is relatively low—per capita consumption is about one quarter of the world average and one tenth of typical developed country consumptions—the contribution of CO_2 is already about 9 percent of the annual world total. Of the CO_2 emissions, it is estimated that around 80 percent comes from the use of fossil fuel as energy sources. The rapid growth of the Chinese economy means that the emissions will continue to increase rapidly unless vigorous efforts are made to improve energy efficiency.

1.2 The basic objective of the study is the development of strategies for reducing greenhouse gas emissions, based on a comprehensive investigation of the current situation and projections for energy use and emissions over the next 15-20 years. The study includes a number of related elements through which the sources and sinks for greenhouse gases are characterized and options for modifying emissions are explored. This report—part of Output 1.2 of the study which addresses the potential for improvements in energy efficiency—summarizes the situation in major energy consuming sectors: industry, transport, agriculture, buildings, coal mining and electricity generation.

1.3 The study was started in early 1992 with formulation of the terms of reference. A team was set up to collect data, to write sector Background Reports, and to participate in case study evaluations. These case studies are analyses of selected technologies with the potential to save energy and reduce greenhouse gas emissions, and with broad applicability in the various sectors. The Chinese counterparts were coordinated through the State Planning Commission (SPC) and team participants were drawn from a wide range of ministries and agencies. The Energy Research Institute of SPC also took part in most aspects of the work.

1.4 The measures reported here for improving energy efficiencies address principally the short- to medium-term potential for energy savings. In general, the impacts of structural changes to sectors and significant shifts to the type of product made in a sector are not included in this report, although it is recognized that such changes could eventually be much more significant than short-term, conventional, "energy conservation measures." These important items are therefore addressed in a separate part of the study.

B. METHODOLOGY

1.5 In summary, the work on Output 1.2 was conducted as follows:

(a) The scope of data requirements and the contents of "Background Reports" were defined. Assignments for team members were made.

(b) The required data were assembled and incorporated in sector Background Reports. The sectors covered were:

   (i) Industry, divided into iron and steel; nonferrous metals (copper, aluminum, lead, zinc); chemicals; petrochemicals; paper; textiles; industrial equipment (fans, motors, boilers, steam traps, etc.)

   (ii) Agriculture

   (iii) Transportation (rail, road, water)

   (iv) Buildings (residential and commercial)

   (v) Coal mining

   (vi) Electricity generation

(c) Preliminary recommendations were made for case studies of energy-saving technologies with potentially wide application in relevant sectors. These were examined further and a final list of 24 case studies agreed.

(d) Field visits were undertaken to plants around China in which the case study technologies have been adopted or have been studied extensively and for which realistic cost data are available. The use of practical data from typical plants was seen as an important element to ensure the findings of the study were representative of commercial operations in a Chinese context.

(e) A one-week seminar was carried out in Beijing to teach project evaluation methods to the main team members involved in the case studies. A standard methodology was thus adopted for all sectors.

(f) The case study analyses were conducted in conjunction with Clemson University. The results are reported in detail elsewhere.

(g) The information given in the Background Reports and the case study analyses was reviewed and put into this shortened report.

(h) Case study data and estimates of potential application of each technology were used to estimate the possible impact on energy use and emissions in 2000 and 2010.

(i) The findings on energy efficiency and the problems faced in each sector were taken into consideration in developing recommendations for short-term actions to promote energy efficiency and thus contribute to reducing emissions of greenhouse gases.

The main work on Output 1.2 was undertaken from early 1992 to the end of 1993.

C. DATA

1.6 The data collected in the course of the study were obtained from a variety of sources. Internal data from various ministries or research institutes were used extensively, together with published national statistics. Although the Background Reports were written in different formats, this final report attempts to present information in a consistent format.

1.7 For the most part, the data are reported for 1990 but some sectors have presented data for 1991. Sometimes there are inconsistencies in the data, particularly when different sources are involved. Central government statistics may be different from the corresponding figures collected by individual ministries. In this report, forecasts of sector outputs and energy use have been given by most of the ministries but there has been no attempt here to ensure consistency between the forecasts. This consistency has been achieved in other parts of the study by using input/output modelling techniques.

2. OVERVIEW OF ENERGY EFFICIENCY

A. Energy Management and Conservation

2.1 This report—and the Background Reports for sectors and subsectors from which it is derived—focusses principally on the short- to medium-term potential for energy savings. Measures already adopted, and most of those proposed, use proven equipment and processes. The typical measures are appropriate for the present time and are likely to continue to be applied for say 15-20 years in existing plants, and as part of the design of new facilities. Important items such as structural changes in Chinese industry and its products are not included in this report, although it is recognized that such changes could be much more significant for energy consumption patterns and emission reduction in the longer term than conventional "energy conservation" as such.

2.2 Other changes that could have a profound effect on energy efficiency include the location of processing plant, of an economic scale based on international standards, near either raw material sources or markets. These plants would gradually replace existing subeconomic-scale facilities dispersed all over the country that are far from both raw materials and energy sources, and distant from their markets. This is also a topic outside the scope of this report.

2.3 All sectors report that energy efficiency has been improved over the last ten years or so in China. In addition, however, all report that more needs to be done and indeed can be done, mostly using similar methods, equipment and processes as before. Most sectors recognize the role of good energy management but there is also a strong desire to see technical solutions to the problem of high energy consumptions. While it is undoubtedly true that new equipment and new processes are essential for continued medium to long-term progress in reducing energy use and emissions of greenhouse gases, the contribution of good management and of more effective operation of existing facilities is often underrated. Also, it is unlikely that the optimum benefits will be obtained from modern equipment and new technologies in the absence of strong energy management.

B. Energy Efficiency Improvement in Specific Sectors

2.4 Each sector and subsector quotes areas where more effort needs to be placed to achieve continuing improvements in energy utilization and reduction or amelioration of pollutant emissions. Major sector or industry-specific items which would contribute to energy savings and lower emissions include the following:

(a) **Iron and Steel**

- Modernization of outdated furnaces and other equipment, and adoption of large-scale processing facilities in place of multiple units of a subeconomic scale.

- Phase out of highly inefficient and severely polluting equipment such as open hearth steel converters and poorly designed and maintained coking plants.

- Further adoption of the continuous casting process.

- Recovery of waste heat and waste gases from processing units for useful application within the same plant, at nearby plants, or for electricity generation for export to the grid.

(b) **Nonferrous Metals**

- Replacement of outdated copper, lead and zinc smelters by new facilities in suitable locations. Most existing plants are at least 25 years old.

- Renovation of large-scale existing facilities for the electrolytic refining of aluminum, and adoption of modern technologies for new plants.

(c) **Cement**

- Replacement of small old plants by large-scale modern plants with high energy efficiency and improved dust emission protection. There are over 5,000 small-scale plants, of which about 2,000 use primitive types of shaft kiln.

- Renovation or replacement of existing large- and medium-scale plants, half of which were built over 40 years ago. This will include replacement of wet process kilns where possible by preheater or precalciner systems.

- Utilization of industrial wastes such as fly ash and coal washery wastes as feed to cement kilns or for the production of blended cements should be encouraged. More blended cements should be produced to meet certain markets where their properties are fully acceptable or preferred (e.g., large-scale hydraulic dams and similar massive structures).

- Electricity generation by heat recovery in old kilns should be evaluated because the economic viability of this technique is suspect. All such plants have been shut down in western countries.

(d) **Flat Glass, Ceramic Tiles, Lime**

- As for much of the buildings material sector, old and outdated plants, many of them very small by world standards, need replacement by larger modern plants.

(e) **Clay Bricks**

- This sector is dominated by TVE plants, many of which are very small and use simple technologies. Plant size is increasing for new TVE plants, however, and there are process developments which result in good energy efficiency. TVE plants should therefore be encouraged to adopt the process developments that are already available when planning new facilities.

- The proportion of hollow or perforated bricks remains very low in China at about 0.3 percent of the total output. In many developed countries, the extent of perforated brick production is high. This type of brick requires less energy to make, consumes less raw material for a given construction volume, and has superior insulating properties in service.

(f) **Paper**

- Adoption of black liquor recovery in more paper plants for energy and caustic soda recovery, and increased utilization of waste materials such as bark, chips and sawdust.

- Increased use of cogeneration in the paper industry.

- Replacement of old small plants by larger modern facilities, in which black liquor recovery and cogeneration investments are more likely to be economic.

(g) **Textiles**

- Replacement of old small plants, as for most other sectors, and greater application of modern technologies and electronic controls.

(h) **Chemicals, Petrochemicals**

- Renovation or replacement of small and medium-scale ammonia plants, of which there are over 1,000 making ammonium bicarbonate. These were mostly built over 20 years ago and are inefficient by typical developed country standards and are too small to reach economic viability by normal evaluation criteria.

- Enterprise scale needs to be reviewed, as there are many small-scale plants which are uneconomic by normal standards and are unlikely to ever reach true commercial viability.

(i) **Equipment**

- Many items of equipment are not up to the standards of similar items on the international marketplace. Technology transfer through licensing agreements should be considered for key items such as certain types of electric motor, industrial scale boilers, steam traps, fans and pumps, controls and instrumentation.

(j) **Coal Mining**

- Old equipment and inefficient items such as ventilator fans and water pumps (and associated motors) need to be replaced by modern energy efficient designs.

- Coal washing and screening facilities are important in providing higher quality coals—and coals of a constant quality—to customers. This would allow higher levels of coal combustion efficiency to be achieved by most users, and sulphur emission levels would also be reduced by selective removal of sulphur compounds in the washing stage.

(k) **Power Sector**

- Old generating plants based on low or medium pressure boilers should continue to be replaced by modern, large, high pressure units.

- Electricity distribution systems need upgrading to take higher loads. Power factor compensation in distribution systems should be improved and many parts of the cable systems require renewal.

- All aspects of electricity distribution losses should be investigated and action taken to reduce losses in order of priorities. As suggested in item (2), certain equipment may need replacement, including transformers.

- Existing large power plants based on fossil fuels should be brought up to higher efficiency by using available technologies such as modern burners and improved heat recovery from combustion gases in water or air preheat systems, and by improving maintenance standards.

C. Actions to Promote Energy Efficiency

2.5 The actions needed to stimulate interest in energy efficiency and to achieve positive results are varied in nature. It is necessary firstly to create an environment in which energy efficiency is seen as a priority because it will bring benefits to the enterprise and the individual. These benefits may be seen in a variety of forms and combinations, such as through higher profitability and higher salaries or bonuses, through better working and safer conditions in the enterprise itself, and as a cleaner and more pleasant environment for living in the area surrounding the enterprise through reduced local pollution. Secondly, it is necessary to provide the skills and tools needed to achieve practical energy saving results in the enterprises.

2.6 Actions at a policy level could include a combination of measures such as the following:

(a) Focussing on energy efficiency as a major contributor to the profitability of enterprises, to an improvement of the local environmental conditions, and to a reduction in global warming. In practice, this means providing incentives to save energy, both in terms of energy pricing policies and policies to promote new investments in energy efficient equipment and processes.

(b) Supporting training to improve energy awareness at a general level and to raise skills in economic analysis and energy related technologies for enterprise and government agencies at all levels, national to local.

(c) Providing funding support to enterprises investing in energy efficient and low polluting processes, through financial incentives or in the form of loans and grants targeted to energy efficiency.

(d) Providing general industrial promotion policies which encourage modernization and restructuring of energy intensive sectors.

(e) Enforcing more effectively the existing regulations for emission control and for the phase out of inefficient products such as outdated electric motor designs.

(f) Encouraging the application of lower energy consuming and cleaner indigenous technologies where appropriate, as these are often better suited to Chinese conditions (e.g., scale, maintenance needs, operator skills) and less costly than technologies used in developed countries. Each case needs thorough evaluation and whatever approach is finally adopted must be justified by the economics of the specific case.

2.7 Specific activities to raise awareness and skill levels can take a wide variety of forms. For example:

(a) Setting up demonstrations of energy efficient equipment and processes, from low cost/no cost items such as energy management systems, improved maintenance procedures, and instrumentation, to high capital investment items such as new higher efficiency boilers. Practical demonstrations in a Chinese context are important to convince enterprise managers of the technical and economic viability of "new" technologies, even though these may already have received broad acceptance internationally.

(b) Promoting a customer service-oriented approach to equipment suppliers through training in modern marketing methods, coupled with customer training to raise awareness of available alternatives and the need for proper economic analyses for equipment selection.

(c) Setting up local technical assistance centers—or raising the skill levels and equipment available in existing centers—to provide stronger support to local enterprises for economic and technical evaluations of both current operations and planned investments. Through local centers, developing the concept of monitoring and targeting at a practical level by applying the technique in local enterprises as a demonstration project.

(d) Setting up specific demonstration and technical assistance programs to encourage the adoption of improved technologies in China. This may be done firstly by creating a better awareness of the capabilities of selected technologies in customers or end-users, and secondly by upgrading Chinese industries to supply the relevant energy efficient products. For example, such programs could be set up for steam traps, variable speed electric motor devices, industrial boilers and associated controls, steam system insulation, and cogeneration applications.

(e) Undertaking specific programs to address problems identified in key sectors, such as a major line loss reduction program for low voltage local electricity distribution systems, a program to study systematically the availability and utilization of industrial wastes (e.g., cement and brick plant feedstock; making synthetic construction materials), and a program to study manufacturing techniques and applications for perforated bricks.

(f) Initiating stronger efforts to upgrade coal quality by washing, screening and briquetting, as this will have a beneficial effect on a wide range of users and allow them to improve the standard of their operations.

3. INDUSTRIAL SECTOR

A. Iron and Steel

Industry Profile and Products

3.1 The iron and steel sector consumed almost 100 million TCE in 1990, accounting for 10 percent of the national energy demand. The sector includes a wide range of activities, such as raw material mining and preparation, iron-making, steel-making, steel rolling and manufacture of finished products, coking and preparation of auxiliary raw materials and refractories, machinery fabrication and repair, ferroalloy production, and various other activities related to iron and steel such as those for making cement with water-granulated slag from blast furnaces.

3.2 In addition to manufacturing facilities, the industry has its own design and scientific research institutes, universities and colleges, hospitals and both living and recreational buildings. In 1990, there were a total of 2,010 units subordinated to the iron and steel industry with 3.67 million personnel. Within the 2,010 units, there were 1,589 operating enterprises:

151	iron ore mines
41	coke plants
656	iron and steel works
182	ferroalloy plants
75	metal product factories
38	carbon products factories
131	refractory factories
166	other enterprises

A further breakdown of these enterprises and both output and energy consumption data are given in Tables 3.1 and 3.2.

3.3 The capacity of the sector in 1990 was 71.2 million tons of steel, 65.3 million tons of pig iron, and 73.4 million tons of rolled steel products (Table 3.3). The actual steel output was 66.35 million tons—ranking China as fourth in the world in terms of steel output—and total output value of the sector was Y 132.5 billion. Within the sector, there are 50 so-called key (or major) enterprises, consisting of 32 iron and steel works, 7 ferroalloy plants, 4 refractory plants, 2 carbon product factories and 5 mining companies. Various statistics for the sector are given in Table 3.4.

Table 3.1: TYPES OF ENTERPRISE AND PRODUCT OUTPUT, 1990

	Key enterpr.	Major local	Local medium and small	Out of sector	Total
Enterprises	102	79	936	472	1,589
Outputs, million tons per year					
Crude steel	45.39	14.90	2.74	3.31	66.35
Pig iron	37.58	14.93	6.55	3.31	62.37
Rolled steel	32.54	12.27	5.00	1.73	51.53
Ferroalloy	0.91	0.20	0.83	4.50	2.38
Carbon products	0.18	0.01	0.15	0.58	0.91
Refractories	2.12	0	1.67	4.29	8.07
Coke	24.75	8.78	5.11	34.63	73.27
Metal products	0.64	0.05	0.53	0.27	1.49

3.4 With respect to the products made in 1990, about 70 percent was ordinary steel and 30 percent high quality steel, including 6.3 percent high alloy steel. Steel is made by three main routes—19.9 percent by the open hearth method, 21.1 percent by electric arc furnaces and 59.0 percent by the basic oxygen process. There were over 20,000 different rolled steel products with a total output of 51.5 million tons; about one third of these products were steel plate and pipe and the remainder consisted of rails, sections and wire (see Table 3.5). In general, the quality of Chinese steel is being progressively improved and 40 percent of output reached international specifications in 1990.

3.5 In 1990, coke production reached 73 million tons, of which 50 million was produced in mechanized coke ovens (68 percent). Of this, output from the metallurgical sector was 75 percent, the rest was made by the chemical, urban construction, coal and other industrial sectors, and TVE coke plants.

3.6 The production of ferroalloy was substantial at 2.3 million tons in 1990 out of a capacity of 3.24 million tons (see Table 3.6).

Energy Use

3.7 The main energy sources for the iron and steel industry are coking coal, steam coal, electricity, fuel oil and natural gas. The total energy consumption for the sector reached 98.7 million TCE in 1990 as reported in Table 3.7 (about 10 percent of national energy use), although the total for all iron and steel-related activities in China was

Table 3.2: BASIC STATISTICS OF KEY IRON AND STEEL ENTERPRISES

Enterprises	Location	Completion time (year)	Processing route	Major products	Output (10^4 t)	Annual energy consumption (coal equivalent) (10^4 t)	SO_2 emissions (t)
Shoudu Iron and Steel Co.	Beijing	1920	ore blast furnace converter rolled product	Steel	435.6	537.0	30,445.37
Tianjin Metallurgical Bureau	Tianjin	-	Pig iron - converter (open hearth) rolled steel	steel	158.5	124.3	21,593.13
Tangshan Iron and Steel Co.	Tanshan, Hebei Province	1944	Ore - blast furnace - converter - rolled product	Steel	157.8	131.0	7,885.11
Xuanhua Iron and Steel Co.	Xuanhua, Hebei Province	1918	Ore - blast furnace	Pig iron	100.9	139.3	5,202.64
Taiyuan Iron and Steel Co.	Taiyuan, Shanxi Province	1939	Ore - blast furnace - open hearth, converter, electric furnace - rolled furnace	Steel (special steel)	179.1	238.2	20,958.04
Baotou Iron and Steel Co.	Baotou, Inner Mongolia	1958	Ore - blast furnace - open herth (converter) - rolled product	Steel	252.3	338.1	31,158.73
Anshan Iron and Steel Co.	Anshan, Liaoning Province	1919	Ore - blast furnace - open hearth (converter) - rolled product	Steel	765.8	852.8	68,863.45
Benxi Iron and Steel Co.	Benxi, Liaoning Province	1910	Ore - blast furnace - converter - rolled product	Steel	236.3	384.4	66,754.10
Fushun Steel Plant	Fushun, Liaoning Province	1933	Steel scrap - electric furnace - rolled product	Steel (special steel)	33.5	33.4	975.31
Dalian Steel Plant	Dalian, Liaoning Province	1937	Steel scrap - electric furnace - rolled product	Steel (special steel)	30.3	31.7	3,368.42
Qiqihaer Steel Plant	Qiqihaer, Heilongjiang Province	1957	Steel scrap - electric furnace - rolled product	Steel (special steel)	47.6	43.4	1,482.79
Shanghai Meishan Metallurgical Co.	Nanjing, Jiangsu Province	1969	Ore - blast furnace	Pig iron	159.5	138.5	19,916.63
Shanghai Metallurgical Bureau	Shanghai	-	Pig iron - open hearth (converter, electric furnace) - rolled product	Steel (special steel)	507.5	329.9	8,117.78
Shuicheng Iron and Steel Co.	Liupanshui, Guizhou Province	1969	Ore - blast furnace - converter - rolled product	Pig iron	53.8	76.1	11,422.41
Shaanxi Steel Plant	Xian, Shaanxi province	1965	Steel scrap - electric furnace - rolled product	Steel (special steel)	14.6	14.7	781.9
Shaanxi Precision Alloy Plant	Xian, Shaanxi Province	1965	Steel scrap - electric furnace - steel	Steel	0.38	-	-
Jiuquan Iron and Steel Co.	Jiayuguan, Gansu Province	1970	Ore - blast furnace - converter - rolled product	Iron	44.6	88.9	8,964.00
Xining Steel Plant	Xining, Qinghai Province	1969	Steel scrap - electric furnace - rolled product	Steel (special steel)	32.0	31.3	1,207.00

Table 3.2: (cont'd)

Enterprises	Location	Completion time (year)	Processing route	Major products	Output (10^4 t)	Annual energy consumption (coal equivalent) (10^4 t)	SO_2 emissions (t)
Shizuishan Iron and Steel Plant	Shizuishan, Ningxia Autonomous Region	1965	Steel scrap - electric furnace - rolled product - steel wire rope	Steel	4.66	-	1,414.00
Baoshan Iron and Steel General Works	Baoshan County, Shanghai	1985	Ore - blast furnace - converter - rolled product	Steel	388.7	309.3	36,131.84
Maanshan Iron and Steel Co.	Maanshan, Anhui Province	1909	Ore - blast furnace - converter (open hearth) - rolled product	Steel	204.1	276.1	11,617.20
Wuyang Iron and Steel Co.	Pingdingshan, Henan Province	1978	Steel scrap - electric furnace - rolled product	Steel (special steel)	10.1	11.9	1,512.50
Wuhan Iron and Steel Co.	Wuhan, Hubei	1955	Ore - blast furnace - converter (open hearth) - rolled product	Steel	474.2	555.3	28,658.27
Daye Steel Plant	Huangshi, Hubei	1918	Pig iron - open hearth (electric furnace) - rolled product	Steel	57.3	47.4	4,922.60
Xiangtan Iron and Steel Co.	Xiangtan, Hunan Province	1959	Ore - blast furnace - open hearth - rolled product	Steel	57.0	89.9	8,104.12
Panzhihua Iron and Steel Co.	Panzhihua, Sichuan Province	1970	Ore - blast furnace - converter - rolled product	Steel	191.4	197.4	31,001.79
Chongqing Iron and Steel Co.	Chongqing, Sichuan Province	1940	Ore - blast furnace - open hearth - rolled product	Steel	83.2	141.5	15,460.75
Chongqing Special Steel Plant	Chongqing, Sichuan Province	1937	Steel scrap - electric furnace - rolled product	Steel (special steel)	28.3	30.6	446.3
Changcheng Special Steel Plant	Jiangyou County	1965	Steel scrap - electric furnace - rolled product	Steel (special steel)	46.0	38.8	1,759.99
Chengdu Seamless Steel Tube Plant	Chengdu, Sichuan Province	1982	Steel scrap - open hearth - rolled product	Steel	47.0	33.8	2,240.63
Guiyang Steel Plant	Guiyang, Guizhou Province	1958	Steel scrap - electric furnace - rolled product	Steel (special steel)	17.1	15.3	7,194.24
Guikzhou Steel Wire Rope Plant	Zunyi, Guizhou Province	1966	Steel scrap - electric furnace - rolled product - steel wire rope	Steel	1.23	-	-
Hanxing Bureau of Metallurgical Mines	Handan, Hebei Province	1951		Ore	318.9	-	2,144.48
Liaoning Magnesite Mining Co.	Haicheng, Liaoning Province	1980		Magnesite	196.5	-	2,480.12
Central Shandong Mining Co.	Zhangjiawa, Shandong Province	1970s		Ore	113.6	-	-

Table 3.2: (cont'd)

Enterprises	Location	Completion time (year)	Processing route	Major products	Output (10^4 t)	Annual energy consumption (coal equivalent) (10^4 t)	SO_2 emissions (t)
Hainan Iron Mine	Changjiang, Hainan Province	1958	-	Ore	427.3	-	548.88
Panzhihua Mining Co.	Panzhihua, Sichuan Province	1970		Ore	885.4	-	125.00
Jinzhou Ferroalloy Factory	Jinzhou, Liaoning Province	1942	Ore - ore smelting furnace	Ferro-alloy	6.2	-	1,260.19
Liaoyang Ferroalloy Factory	Liaoyang, Liaoning Province	1949	Ore - ore smelting furnace	Ferro-alloy	6.2	-	2.59
Jilin Ferroalloy Factory	Jilin, Liaoning Province	1956	Ore - ore smelting furnace	Ferro-alloy	23.5	-	1,864.85
Hunan Ferroalloy Factory	Xiangxiang, Hunan Province	1962	Ore - ore smelting furnace	Ferro-alloy	6.6	-	521.64
Emei Ferroalloy Factory	Emei, Sichuan Province	1972	Ore - ore smelting furnace	Ferro-alloy	4.7	-	467.72
Zunyi Ferroalloy Factory	Zunyi, Guizhou Province	1966	Ore - ore smelting furnace	Ferro-alloy	9.2	-	441.00
Northwest Ferroalloy Factory	Lanzhou, Gansu Province	1975	Ore - ore smelting furnace	Ferro-alloy	7.4	-	121.90
Jilin Carbon Factory	Jilin, Jilin Province	1955		Carbon product	9.98	-	562.60
Lanzhou Carbon Factory	Lanzhou, Gansu Province	1966		Carbon product	4.02	-	364.76
Luoyang Refractory Factory	Luoyang, Henan Province	1959		Refrac-tory	12.02	-	240.33
Northwest Refractory Factory	Yao County, Shaanxi Province	1970		Refrac-tory	3.78	-	720.00
Deyang Refractory Factory	Deyang, Sichuan Province	1970		Refrac-tory	3.90	-	-
Guiyang Refractory Factory	Guiyang, Guizhou Province	1958		Refrac-tory	6.17	-	7.50

106.89 million TCE. Energy consumptions by source are shown in Figure 3.1 and Tables 3.8 and 3.9. Table 3.10 gives indications of energy prices, which are steadily increasing for all enterprises, and shows the cost of energy now represents well over 20 percent of total manufacturing costs.

Table 3.3: CAPACITY AND OUTPUT FOR MAJOR PRODUCTS, 1990
(million tons)

Major products	Capacity	Actual output
Crude steel	71.21	66.35
Pig iron	65.31	62.37
Rolled steel	73.38	51.53
Coke, total	73.43	73.27
mechanized	50.87	50.03
Ferroalloys	3.24	2.38

3.8 About two thirds of the energy used in the sector is for a few major process stages—coking, sintering, blast furnace operation, steel conversion and rolling (see Table 3.11). About 30 percent is used for all auxiliary processes and services. The main energy consuming equipment consists of furnaces, blast furnaces and converters and detailed information on such equipment in key enterprises is given in Table 3.12.

3.9 A reliable supply of electricity is important and the majority of enterprises receive power from the national transmission system for which the average generating efficiency is 30.4 percent. About 56 billion kWh of electricity were consumed in the iron and steel industry in 1990. A number of the larger plants generate their own electricity with varying levels of efficiency: for example, Anshan Iron and Steel Co. operates quite old facilities at about 31 percent while the new Baoshan plant reaches 39 percent. However, many older plants are operating under 30 percent, some as low as 25 percent. The total self generated electricity amounted to 10.4 billion kWh in 1990, about 20 percent of plant demand.

3.10 Steam is also an important energy source: except for a few plants, steam is obtained from self contained boilerhouse systems. Many of the older boilers are operated only to make steam for electricity generation although combined heat and power systems are becoming more common. Table 3.13 gives some typical boiler efficiency figures, which vary from about 60 to 83 percent.

Specific Energy Consumption

3.11 There is a wide range of energy intensities shown by enterprises in this sector: this is illustrated in Table 3.14. Much of the equipment in this sector is quite old and the technologies are relatively backward in many plants. Efficiencies are therefore generally lower than for the corresponding activities in developed countries but efforts to modernize the industry have been pursued vigorously in recent years.

Table 3.4: BASIC STATISTICS FOR THE STEEL INDUSTRY

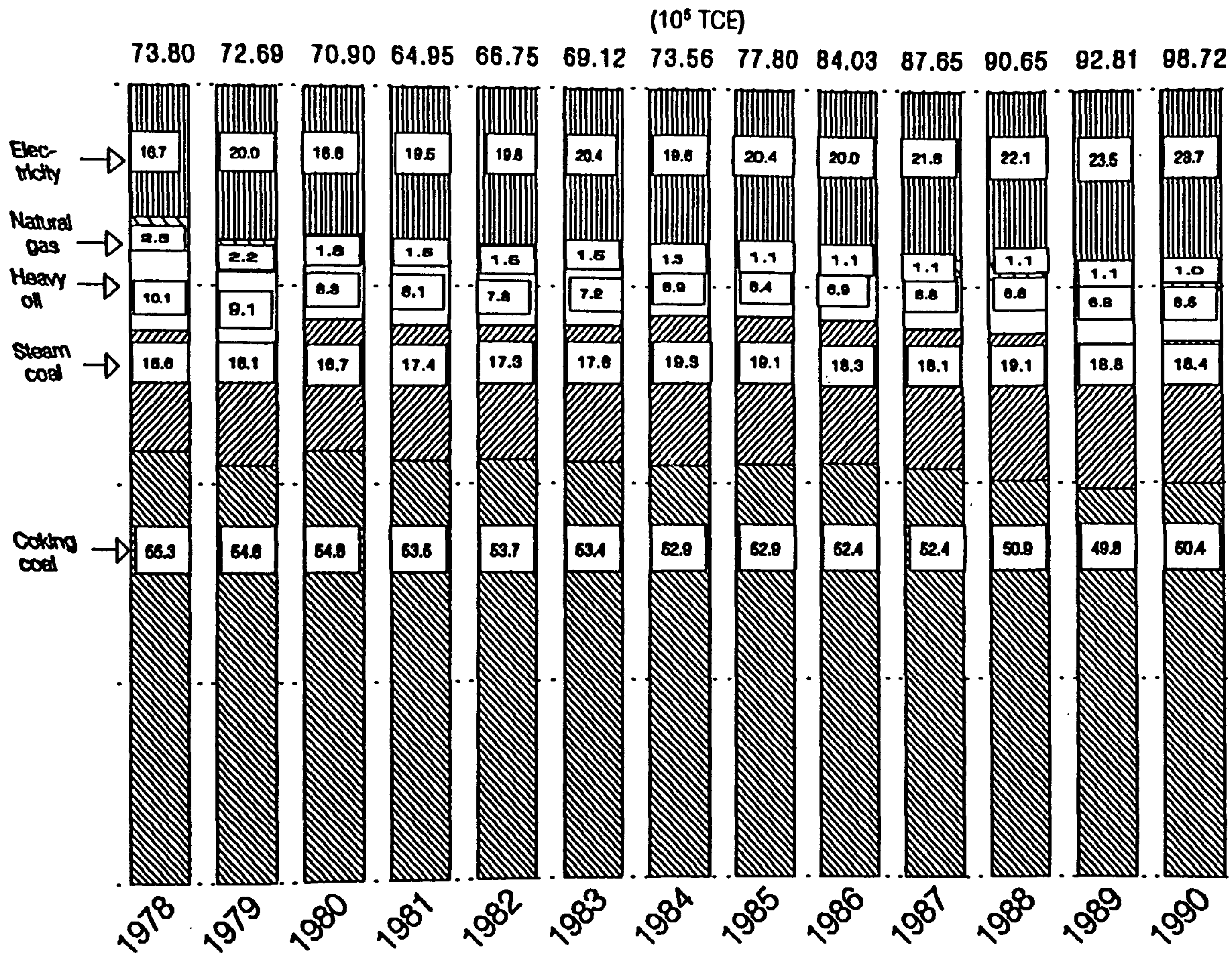
Item	Unit	1985	1986	1987	1988	1989	1990
Number of enterprises and institutions		1,925	2,002	2,022	2,100	1,931	2,010
Gross industrial output value /a	Y 10^8	449.6	499.98	547.05	567.20	594.25	631.76 (1,325.43)
Net industrial output value /b	Y 10^8	180.6	205.05	242.26	283.01	325.83	322.13
Steel output	10^4	4,679.0	5,220.8	5,627.61	5,943.0	6,158.7	6,634.86
Total energy consumption /c	10^4	7,829.0	8,457.5	8,821.43	9,101.21	9,308.76	9,871.84
Total number of staff and workers (year-end)	10^4 persons	328.4	399.13	349.06	356.93	360.70	366.80
Number of enterprises		1,318	1,393	1,444	1,478	1,550	1,589
Gross industrial output value /a	Y 10^8	440.3	489.2	534.70	551.29	585.13	621.9
Net industrial output value /b	Y 10^8	175.8	199.8	236.26	276.78	321.81	211.78
Output of major industrial products:							
Steel	10^4 t	4,679.40	5,220.8	5,627.61	5,943	6,158.72	6,634.86
Finished rolled steel products	10^4 t	3,692.31	4,048.0	4,385.57	4,689.22	4,859.11	5,153.21
Pig iron	10^4 t	4,383.68	5,063.9	5,503.18	5,704.0	5,820.03	6,237.31
Coke	10^4 t	4,794.65	5,267.0	5,790.6	6,107.62	8,623.99	7,326.63
Raw iron ore	10^4 t	13,735.0	14,945.0	16,142.5	16,769.86	17,185.40	17,934.36
Iron concentrate	10^4 t	4,380.20	4,714.0	5,200.79	5,300.64	5,444.90	5,706.90
Ferroalloy	10^4 t	149.18	159.6	184.61	208.45	236.98	238.27
Refractory	10^4 t	614.18	596.4	682.88	827.12	821.11	807.38
Carbon product	10^4 t	60.56	34.18	59.02	76.24	88.32	91.27
Total energy consumption /c	10^4 t	7,779.63	8,403.9	8,765.4	9,064.8	9,283.56	9,871.84
Comprehensive energy consumption per ton steel	eq. coal, t/t steel	1.746	1.705	1.674	1.647	1.636	1.600
Total number of staff and workers (year end)	10^4 persons	268.14	280.75	289.08	304.4	309.1	315.3
Financial indexes:							
Original value of fixed assets (year-end)	Y 10^8	598.13	713.3	793.64	889.3	994.89	1,114.38
Net value of fixed assets (year-end)	Y 10^8	397.00	502.8	553.4	621.4	693.60	774.91
Total funds /d	Y 10^8	505.83	598.0	701.47	772.55	878.79	1,013.18
of which: Net value of fixed assets	Y 10^8	375.53	433.52	510.53	658.23	634.01	701.01
Quota circulating funds	Y 10^8	130.33	164.48	190.94	204.32	244.78	312.17

/a At 1980 constant prices, in parenthesis, at 1990 constant prices.
/b At current prices by allocation method.
/c Coal equivalent, 10^4 tons.
/d At annual average balance.

Energy Efficiency Trends

3.12 The iron and steel sector has placed strong emphasis on energy efficiency for more than 15 years: overall energy consumption has been cut from 2.5 to 1.6 TCE/t (Table 3.15 and Figure 3.2). From 1978 to 1982, the work started by stressing energy awareness, improving management and cutting obvious wastes and losses. Annual energy saving amounted to about 7 percent.

Figure 3.1: PRIMARY ENERGY CONSUMPTION IN THE IRON AND STEEL INDUSTRY, 1990



Percentages are shown in the diagram.

Table 3.5: PRODUCTION OF ROLLED STEEL PRODUCTS
(Percentage of total production)

Type of product	1985	1986	1987	1988	1989	1990
Steel items for railways	3.9	3.5	3.4	3.4	3.3	3.2
Steel sections	45.1	45.4	44.6	42.7	41.1	40.0
Wire rods	16.2	15.8	15.8	17.0	18.2	19.4
Steel plates	23.5	23.4	23.7	25.2	25.5	23.4
Steel pipes	8.7	7.9	9.3	8.3	8.4	8.4
Steel strip	2.2	2.4	2.8	3.0	3.1	3.3
Miscellaneous	0.4	1.6	0.4	0.4	0.4	2.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.6: FERROALLOY PRODUCTION, 1990

Percentages:	
Ferrosilicon	32.65
Carbon ferromanganese	10.05
Silicon manganese	16.44
Blast furnace ferromanganese	17.75
Other alloys	23.11
Total (%)	100.00
Total Output (million tons)	2.383

3.13 From 1982 to 1986, energy conservation was extended to iron ore mines and ferroalloy, refractory, carbon product, metal product and other enterprises. Laws and regulations were introduced, working procedures improved, and a variety of energy saving technical measures introduced. These included converter gas recovery, continuous casting, multi-lance oxygen blowing of open hearth furnaces, blast furnace coal injection, and greater utilization of waste heat. During the period, annual energy saving was almost 3 percent.

3.14 From 1987, further energy saving was pursued, although this became more difficult as operations developed towards smaller batches and higher quality. Shortage of funds and inadequate investment led to less energy saving, which dropped to an annual rate of less than 1 percent.

Table 3.7: RELATION OF SECTOR ENERGY USE TO NATIONAL ENERGY DEMAND

	1980	1985	1986	1987	1988	1989	1990
Energy consumption, million TCE							
Iron and steel industry	70.90	77.80	84.03	80.05	91.01	91.55	98.72
National	802.75	766.82	808.50	866.32	929.97	969.34	980.00
Iron and steel industry as a percentage of national demand	11.76	10.15	10.39	9.24	9.79	9.44	10.07
Index of energy use by the steel industry	100.0	109.7	118.5	112.9	128.4	129.1	139.2

Table 3.8: TYPE OF ENERGY CONSUMED, 1980-90

	Units	1980	1985	1986	1987	1988	1989	1990
Total demand	10^6 TCE	70.90	77.80	84.03	87.65	90.65	92.84	98.72
Coal	10^6 TCE	59.63	86.95	70.87	73.42	75.47	75.92	80.69
	%	71.3	72.0	70.7	70.5	70.0	68.6	68.8
Electricity	TWh	31.48	38.59	43.28	46.89	49.48	53.91	57.96
	%	18.6	20.4	20.0	21.6	22.1	23.3	23.7
Heavy oil	10^6 t	4.21	3.51	4.13	4.15	4.32	4.45	4.49
	%	8.3	6.4	6.9	6.8	6.8	6.8	6.5
Natural gas	10^6 m^3	957	677	733	730	796	790	742
	%	1.8	1.1	1.1	1.1	1.1	1.1	1.0

3.15 Many energy inefficient technologies and practices have been eliminated. Small blast furnaces (size under about 100 m^3), electric furnaces and converters with capacities under 5 tons, ore heating furnaces under 1,800 KVA are being shut down. Half of the obsolete and inefficient blowers, pumps, transformers and electric motors in the industry are estimated to have been replaced or modified.

Table 3.9: ENERGY CONSUMPTION DATA FOR THE IRON AND STEEL INDUSTRY, 1990

Sector/Subsector	Output (10^3)	Energy consumed: Stm. coal	Cok. coal	Coke	Oil	Nat. gas ($10^6/m^3$)	Total fuel (10^3 TCE)	Electricity: 10^6 kWh	10^3 TCE	Total energy 10^3 TCE
Whole nation	66,348									
Iron and steel industry	63,035	25,372	55,318	46,241	4,486	742	75,302	57,965	23,418	98,720
of which:										
Key enterprises (steel)	45,394	984	33,859	18,510	3,320	514	36,863	20,731	8,395	45,258
Local enterprises (steel)	17,641	299	21,459	14,554	344	60	19,303	8,609	3,497	22,800
Iron ore mines	166,339	791	-	800	-	-	562	6,061	2,440	3,002
Ferroalloy	1,933	398	-	962	156	-	512	9,748	3,936	4,448
Refractory material	3,786	692	-	699	89	-	619	2,203	890	1,509
Carbon product	329	49	-	694	14	-	603	1,865	713	1,316
Other	-	22,159	-	10,022	563	168	16,840	8,748	3,547	20,387
Nonsector (steel)	3,313	-	-	-	-	-	-	-	-	-

Table 3.10: ENERGY PRICES FOR THE IRON AND STEEL INDUSTRY

Year	Energy price (Y/t coal equivalent): Key enterprise	Local major enterprise	Percentage of energy to cost: Key enterprise	Local major enterprise
1981	84.4	-	21.38	-
1982	85.8	-	22.18	-
1983	96.4	-	23.36	-
1984	96.2	-	22.70	-
1985	108.1	-	21.50	-
1986	116.1	79.2	20.36	23.54
1987	125.4	83.3	19.88	21.78
1988	150.9	109.9	20.90	22.86
1989	192.5	142.1	22.17	25.32
1990	230.3	161.6	22.81	25.97

Note: The statistics and average value cannot be obtained to the energy out-of-plan because of its great difference in region, time and variety.

3.16 New energy saving facilities have been installed, e.g., 122 continuous casting machines, bringing the extent of continuous casting up to 28 percent (compared with 90 percent in many developed countries). Blast furnace coal injection has been adopted in 75 percent of key enterprises; 40 percent of steel converters recover by-product

Table 3.11: ENERGY CONSUMED BY MAJOR MANUFACTURING PROCESSES, 1990

	Coke making	Sintering	Iron making	Steel making	Initial rolling	Steel rolling	Ferro-alloys
Output 10^6 tons	37.71	87.03	59.06	63.04	48.23	49.80	1.93
Energy use (10^6 tce)	7.60	8.02	34.11	6.66	3.88	6.88	4.45
Energy use as % of sector use /a	7.7	8.1	34.6	6.7	3.9	6.2	4.5

/a Total for these processes amounts to 71.7 percent.

gas. Four dry coke quenching systems have been installed. The concept of centralized energy centers has been utilized in large plants.

3.17 As a result of conservation efforts, which of course continue, steel output was increased 1.3 times from 1978 to 1990 while energy use increased by 45 percent from 73.8 to 98.7 million TCE.

Potential for Improvement

3.18 Efforts to save energy are continuing as follows:

(a) Energy awareness is being promoted to all levels of staff. Rules and regulations for the energy management of enterprises have been set up, including procedures for carrying out energy balances and comparing consumption with norms.

(b) Tests on operating equipment are made to check thermal efficiency. Upgrading of furnaces, ovens, processes and enterprises is carried out in parallel.

(c) Many energy saving measures have been disseminated to operating plants (see list above for typical examples).

3.19 Although further energy efficiency improvements are becoming more difficult to find and more expensive to make, there remain cost effective opportunities to save energy in the industry. For example, major savings will be achieved through replacement of backward technology such as open hearth steel furnaces and rehabilitation of reheat furnaces in rolling mills. Small-scale facilities will have to be expanded and modernized to improve efficiency, or shut down. Steel and associated product qualities will have to be improved to reduce material consumption and avoid the need for still

Table 3.12: MAJOR PRODUCTION EQUIPMENT IN THE IRON AND STEEL SECTOR

Equipment	Grouping					Heat efficiency (%)
Iron-making blast furnace						
Grouping based on volume (m^3)	>1000	50-999	200-499	50-199	<50	80-85
Number (unit)	31	21	82	200	796	
Volume (m^3)	47,216	14,267	23,691	17,409	14,011	
Steel-making open hearth furnace						
Grouping based on volume (t)	>500	300-499	100-299	<100	-	
Number (unit)	9	11	16	32		30
Tonnage (t)	4,500	3,300	2,150	1,341.1		
Furnace hearth area (m^3)	911.1	768.8	857.9	999.6		
Steel-making electric furnace						
Grouping based on volume (t)	>15	5-14.9	3-4.9	1-2.9	<1	
Number (unit)	65	494	301	332	211	60
Tonnage (t)	1,676	3,000	939	500.1	104.7	
Power factor (kVA)	797,000	1,979,750	676,830	415,230	135,889	
LD converter						
Grouping based on volume (t)	>100	50-99	30-49	10-29	<10	
Number (unit)	7	11	11	76	66	45-50
Tonnage (t)	1,380	550	330	1,976	385	
Iron ore sintering machine						
Grouping based on area (m^2)	>130	51-129	36-50	<35		
Number (unit)	14	36	36	113		75-80
Area (m^2)	2,455	2,898	2,681	2,444.35		
Oxygen generator						
Grouping based on capacity (m^3)	>10000	5000-9999	3000-4999	1000-2999		
Number (unit)	22	29	52	85		
Capacity (m^3/hr)	317,000	176,500	174,350	141,125		
Mechanized coke oven						
Grouping based on number of carbonizers (unit)	>65	36-64	19,35	<19		
Number (unit)	33	82	174	77		50-55
Number of carbonizers (unit)	2,255	3,429	4,434	1,193		
Ferroalloy blast furnace						
Grouping based on volume (m^3)	>225	100-224	50-99	<49		
Number (unit)	4	11	9	2		75-80
Volume (m^3)	1,065	1,100	642	73		
Ferroalloy electric furnace						
Grouping based on power factor	>5000	3000-4999	1500-2999	<1500		
Number (unit)	139	146	450	215		50-55
Power factor (kVA)	1,232,800	477,600	343,910	206,975		

greater production levels with corresponding increased energy consumption. All enterprises need to emphasize the role of good management.

Table 3.13: CONVERSION EFFICIENCY OF POWER BOILERS OF SEVERAL ENTERPRISES

	Steam conversion efficiency (%)
Typical enterprises	
Shoudu Iron and Steel Co.	74.0
Anshan Iron and Steel Co.	78.1
Jiuquan Iron and Steel Co.	78.3
Maanshan Iron and Steel Co.	75.8
Panzhihua Iron and Steel Co.	83.1
Hanzhou Iron and Steel Works	60.3
Anyan Iron and Steel Co.	65.9

3.20 Some specific measures expected to be implemented in the iron and steel industry in the period to 2010 are illustrated in Table 3.16: these include several specific targets for improvement, such as increasing continuous casting to over 50 percent of output. Other measures expected to receive priority attention include direct current electric steel-making, enhanced heat and waste gas recovery, pulverized coal injection to blast furnaces, reheat furnace renovation, cogeneration, variable speed motors for rolling mill drives, and replacement of inefficient small boilers. Estimates of energy saving potential are given in the table.

3.21 It is evident that there remain large differences in energy consumption per unit steel production between China and advanced countries. Differences in the scale of equipment are of course a major factor. For example, there were 1,130 blast furnaces in China in 1990, with an average pig iron output of 52,000 tpy. In Japan, the average is almost 240,000 tpy. Small equipment using backward technology obviously results in high energy consumptions. To effect changes in the sector as a whole, very large capital investments will be needed over many years.

Projected Industry Outputs and Energy Consumption

3.22 The iron and steel sector is expected to continue to expand rapidly. Steel output is likely to be about 110 million tons per year by 2000 and 140 million tpy by 2010. Energy consumption per ton of steel should be reduced to 1.45 and 1.3 TCE/t by 2000 and 2010 respectively (Table 3.16).

Table 3.14: ENERGY OUTPUTS AND CONSUMPTIONS, IRON AND STEEL ENTERPRISES (1990)

Category of enterprises	Output of major products (10,000 t)	Total energy consumption (coal equiv. 10^4 t)	Comprehensive energy consumption (coal equiv., t/t)
1. Integrated iron and steel works	steel: 4,449	5,525	1.242
(a) Key enterprise	3,242	3,902	1.202
(b) Local major enterprise	1,193	1,494	1.311
(c) Local small enterprise	67	129	1.917
2. Ordinary steel enterprise	steel: 1,086	589	0.541
(a) Key enterprise	719	319	0.444
(b) Local major enterprise	236	152	0.644
Local small enterprise	132	118	0.896
3. Special steel enterprise	132	118	0.896
4. Iron-producing enterprise	pig iron: 1,359.4	1,671.2	1.211
(a) Key enterprise	474.1	562.3	1.186
(b) Local major enterprise	356.4	407.3	1.143
(c) Local small enterprise	528.9	701.6	1.327
5. Steel rolling enterprise	steel product: 816.1	230.8	0.283
(a) Local major enterprise	191.6	59.6	0.311
(b) Local small enterprise	624.5	171.2	0.271
Total		8,377.2	85.6%/a
Key enterprise		5,144	52.6%
Local major enterprise		2,113	21.6%
Local small enterprise		1,119.2	11.4%

/a Percentage in the industry.

Generic Investment Options

3.23 A number of technologies were identified as having widespread replication potential in the iron and steel sector, from which the following energy efficiency measures were selected for examination in detail as case studies. For these, actual plant data were collected from various steel works around China to ensure the data on technical performance and costs were reliable. The four items studied for the iron and steel industry were as follows:

(a) M1 Replacement of open hearth steel converters by the basic oxygen process.

The open hearth converter (OH) was the traditional method of making steel from pig iron but consumes large amounts of energy and is responsible for serious pollutant emissions. The OH method has been superseded by the

Table 3.15: SPECIFIC ENERGY CONSUMPTIONS, 1978-90

Year	1978	1980	1985	1990	Decrease in 1990 compared to 1978 (%)	Annual average decrease (%)
Comprehensive energy consumption of iron and steel industry (coal equiv., t/t steel)	2.524	2.039	1.746	1.611	36.17	3.87
Comparable energy consumption of iron and steel industry (coal equiv., t/t steel)	1.55	1.30	1.12	1.03	33.55	3.73
Comprehensive energy consumption of key enterprises (coal equiv., t/t steel)	1.757	1.461	1.295	1.202	31.59	3.28
Comparable energy consumption of key enterprises (coal equiv., t/t steel)	1.400	1.201	1.062	0.997	28.79	3.03
Energy consumption of operating processes of key enterprises (coal equiv., kg/t product)	-	-	-	-	-	-
Coke making	312	196	183	184	15.60	1.63
Sintering	104	95	85	77	25.98	2.70
Iron making	562	531	514	509	9.43	0.97
Open hearth	233	200	156	123	47.21	5.50
Converter	143/a	107/a	39	28	-	-
Electric furnace	403	381	325	296	26.55	2.62
Steel rolling	281	157	152	135	51.96	6.45
Comprehensive energy consumption of local major enterprises (t coal equiv./t steel)	3.081	2.233	1.720	1.436	53.39	6.29
Comparable energy consumption of local enterprises (t coal equiv./t steel)	2.320	1.554	1.220	1.043	55.04	6.58
Energy consumption of operating processes of local major enterprises (t coal equiv./t product)	-	-	-	-	-	-
Coke making	235	267	196	188	20.00	2.30
Sintering	135	120	106	86	36.30	3.62
Pelletizing	65 (1979)	74	63	53	18.46	2.40
Iron making	674	613	585	557	17.36	1.72
Converter steel making	83	88	71	58	30.12	3.06
Electric furnace steel making	439	367	325	317	27.79	2.64
Breaking down	199	149	112	110	44.72	2.64
Steel rolling	230 (1979)	209	138	127	44.78	6.38

/a Including energy consumption of cupola.

Table 3.16: FORECASTS OF OUTPUT, ENERGY CONSUMPTION AND POLLUTANT DISCHARGES FOR 2000 AND 2010

Item		Unit	1991	2000	2010
Steel:					
Total output (capacity)		10^6 t	71.0	100.0	140.0
Output out of iron and steel industry		10^6 t	3.81	3.80	4.00
Comprehensive energy consumption per ton steel		t coal equiv.	1.601	1.45	1.30
Energy Consumption:					
Total consumption		10^6 t coal equiv.	103.21	140.65	176.80
in which:	Coking coal	10^6 t	59.14	81.26	106.08
	Fuel coal	10^6 t	26.54	39.00	54.08
	Heavy oil	10^6 t	4.41	4.92	5.57
	Natural gas	10^9 m^3	0.72	1.05	1.35
	Electric power	10^9 kWh	59.9 (110)/a	70.3 (140)/a	90.9 (280)/a
	Coke /b	10^6 t	4.57	4.35	-
Discharging Volume:					
Dust		kg/t steel	9.5	8	3.5-4.0
SO_2		kg/t steel	10-13	8.5	4.0
NO_x		kg/t steel	1.0	0.8	0.5
CO_2		kg/t steel	2,500-3,000	2,200-2,700	2,000-2,400

Note: (1) The equipped ratio of environmental protection facilities will be up to 100 percent by the year 2000.
(2) The level of environmental protection facilities will reach the international level of the end-1980's by the year 2010.

/a Figure in parentheses indicates the amount of self-generated power.
/b Purchased coke.

basic oxygen furnace (BOF) which is self sufficient in energy and from which fuel gas can be recovered. The last OH furnaces were shut down in most western countries by the early 1980s. In China, the outdated OH process still represents almost 20 percent of steel-making capacity.

(b) M2 Replacement of ingot casting by the continuous casting process.

In the traditional steel-making process, molten steel is poured from the converter into molds and ingots are produced. After cooling and solidifying, these are transferred to reheat furnaces where they are raised to a high temperature again prior to rolling into the required products such as bars, billets or sheets. As cooling and reheating is very wasteful of energy, continuous casting and rolling of steel has been developed and applied in many countries. The process saves energy and reduces metal losses through lower scale and scrap production. While the average percentage of steel processed by continuous casting in the world is about 60 percent, in China it is about 23 percent.

(c) M3 Renovation of reheat furnaces in rolling mills.

The rolling of steel products is an important activity and consumes about 70 percent of the total energy used in steel-making. The operating efficiency of reheat furnaces is therefore a key item in achieving good energy efficiency. Many reheat furnaces in China are however in poor physical condition and are only able to achieve quite low efficiencies. Renovation of the furnaces, equipping them with new burners and improved combustion air preheat, and applying modern instrumentation and controls, has broad application throughout the steel industry.

(d) M4 Recovery of blast furnace top gas for cogeneration.

In modern integrated steel works, blast furnace top gas is normally recovered as fuel gas for furnaces and coke ovens around the plant. In plants producing only pig iron from blast furnaces, there are usually few applications for fuel gas and therefore many plants in China discharge gas in excess of their own requirements directly to atmosphere. This is a waste of energy and is a major source of pollution. The gas may be recovered and used to generate both steam and electricity in a modern cogeneration system.

3.24 Based on data from plants in China where the proposed measures have either been implemented or are planned, rates of return and payback periods (which include construction time) were estimated:

		IRR, %	Payback, years
M1	Replacement of open hearth	16.1	13
M2	Continuous casting	18.6	9
M3	Renovation of reheat furnaces	36.7	1
M4	BF gas recovery	28.2	7

3.25 In addition to cost data, the energy consumption and pollutant emission characteristics of plants with and without the technologies were determined. To calculate the likely contribution of each measure to energy saving and reduction of greenhouse gas emissions, sector characteristics were then used and rates of adoption of each technology by 2000 and 2010 were estimated, taking into account the calculated rates of return and payback periods. Forecasts were made for "business as usual" and "accelerated" scenarios, where the "accelerated" case assumes major awareness campaigns and promotional efforts to persuade enterprise managements to adopt measures and invest in energy efficiency. The forecasts were as follows:

	1990	2000	2010
M1 Replacement of open hearth (million tpy steel)			
BAU Open Hearth	11.7	8.7	8.7
BOF	0.0	3.0	3.0
Accel. Open Hearth	11.7	8.7	0.0
BOF	0.0	3.0	11.7
M2 Continuous casting (million tpy steel)			
BAU Ingot casting	47.6	45.8	31.4
Continuous casting	14.8	16.6	31.0
Accel. Ingot casting	47.6	45.8	12.5
Continuous casting	14.8	16.6	49.9
M3 Renovation of reheat furnaces (million tpy rolled)			
BAU Old furnaces	50.0	8.3	0.0
Renovated furnaces	0.0	41.7	50.0
Accel Old furnaces	50.0	0.0	0.0
Renovated furnaces	0.0	50.0	50.0
M4 BF gas recovery (million tpy pig iron)			
BAU BF capacity, no recov.	10.0	4.0	0.0
Capacity with recovery	0.0	6.0	10.0
Accel. BF capacity, no recov.	10.0	2.0	0.0
Capacity with recovery	0.0	8.0	10.0

3.26 Details of the present levels of use of the various technologies and the assumptions made regarding future adoption are given in Appendix A, together with the energy consumption and emissions factors used in the calculations.

Projected Impacts on Energy and Emissions

3.27 Using the BAU and accelerated forecasts indicated above, the expected impacts on the iron and steel sector energy use were calculated as follows:

	Savings 10^3 TCE/yr by 2000		Savings 10^3 TCE/yr by 2010	
	BAU	Accel.	BAU	Accel.
M1 Replace open hearth	146	146	146	568
M2 Continuous casting	73	73	658	1,425
M3 Reheat furnaces	459	550	550	550
M4 BF gas recovery	296	394	493	493

3.28 Reductions in CO_2 emissions were forecast as follows:

	CO_2 reduction 10^3 TPY by 2000		CO_2 reduction 10^3 TPY by 2010	
	BAU	Accel.	BAU	Accel.
M1 Replace open hearth	154	154	154	602
M2 Continuous casting	48	48	428	928
M3 Reheat furnaces	296	355	355	355
M4 BF gas recovery	237	316	395	395

Emissions

3.29 Furnaces and ovens are the main sources of pollutants such as SO_2 and CO_2. Particulate emissions are also important in this industry. Tables 3.17 and 3.18 give some information on the current generation and discharge of pollutants from various processes.

3.30 Various measures have been taken to improve the situation. Slags are recovered from blast furnaces, steel converters and ferroalloy plants for utilization in cement production. Iron and steel plant operating equipment is now being fitted with dust

Table 3.17: GENERATION OF POLLUTANTS BY THE IRON AND STEEL INDUSTRY
(Units = kg per ton of product)

Products	Dust	CO_2	SO_2	NO_X	Other compounds	Waste-water (m^3/t)	Waste slag
Iron ore	-	-	-	-	-	-	6,000-8,000
Concentrate	-	-	-	-	-	-	-
Sinter	25	176	5	-	-	6-9	-
Coke	5	1,134	21	0.37	0.77	0.2-0.3	-
Pig iron	50	675	-	-	-	10-15	500
Ingot:							
Open hearth steel	12-15	137	-	-	-	1-3	150
Converter steel	16-25	146	-	-	-	1-3	150
Electric steel	2-10	40	-	-	-	1-3	150
Breaking down	-	165	-	-	-	2-6	0.3-0.5/a
Hot rolling	-	268	-	-	-	10-15	0.5-1.0/b
Coal consumption for steam /b	10-30	2,000	10-20	3.6	-	-	200
Ferroalloy	20-30	1,730	-	-	-	-	1,500
Overall discharging volume per ton steel	120-130	2,500-3,000	25-26	-	-	-	-

/a Quantity of scale.
/b The average value from combustion of coal in boilers.

collection facilities, such as wet dust scrubbing systems, filter bags and electrostatic filters. Excluding steel-making electric furnaces and certain ferroalloy furnaces, it is estimated that dust removal equipment is installed on 90 percent on dust producing furnaces and ovens. Processes releasing water with organic contaminants such as coke ovens and rolling mills are about 90 percent equipped with wastewater treatment systems: these include biological and chemical treatment of coking oven water, and deoiling and filtering of rolling mill effluents. Indications of the levels of adoption of various environmental protection facilities are given in Table 3.19. As a result of efforts made in the sector, emissions and the levels of waste treatment have been improved significantly (Table 3.20).

Table 3.18: DISCHARGE OF POLLUTANTS BY THE IRON AND STEEL INDUSTRY
(Units = kg per ton of product)

Products	Dust	CO_2	SO_2	NO_X	Other compounds	Waste-water (m^3/t)	Waste slag	Equipping rate of environmental protection facilities (%)
Iron ore	-	-	-	-	-	-	6,000-8,000	-
Concentrate	-	-	-	-	-	1-2	-	Wastewater, 100
Sinter	6.25	176	5	-	-	-	-	Dedusting, 94-100
Coke	1.25	1,134	1.0	-	-	0.02-0.03	-	Biochemical, 90
Pig iron	2.5	675	-	-	-	1.5-2.0	500	Dedusting, 91
Ingot:								
OH steel	3.0-3.8	137	-	-	-	-	150	Dedusting, 91
BOF steel	2.5	146	-	-	-	1-3	150	100
EAF steel	3-12	40	-	-	-	-	150	61
Breaking down	-	165	-	-	-	1-2	-	Wastewater, 95
Hot rolling	-	268	-	-	-	1-2	-	Wastewater, 95
Coal combustion for steam /a	7.5	2,000	10-20	3.6	-	-	200	-
Ferroalloy	12-25	1,730	-	-	-	-	1,500	-
Overall discharging volume per ton steel	9.5	2,500-3,000	10-13	1.0	-	-	-	-

/a The average value from combustion of coal in boilers.

B. NONFERROUS METALS

Industry Profile and Products

3.31 In 1990, the nonferrous metals industry consisted of 917 enterprises producing metals and 240 organizations engaged in prospecting and construction, conducting scientific research, and operating universities and polytechnic schools. The total employment was 1.37 million personnel for all branches of activity.

Table 3.19: ENVIRONMENTAL PROTECTION FACILITIES FOR MAJOR EQUIPMENT

Production equipment	Environment protecting facilities	Equipping rate (%)
Sintering machine	Fume dedusting in the front of machine	100
Sintering machine	Fume dedusting in the end of machine	94
BOF	First dedusting of fume	100
EAF	First dedusting of fume	81
OH	First dedusting of fume	91
Mineral dressing	Wastewater purification and reusing	100
Coke oven	Wastewater biochemical treatment	100
Blast furnace	Wastewater recirculating use	90
BOF	Wastewater recirculating use	100
Rolling mill	Wastewater recirculating use	95

Table 3.20: POLLUTANT EMISSIONS AND EXTENT OF TREATMENT

	1981	1990
Ratio of waste gas treatment (%)	41	87
Emission of SO_2 per ton steel (kg)	14	10
Emission of dust per ton steel (kg)	36	17
Ratio of wastewater treatment (%)	27	93
Recovery rate of iron bearing slurry (%)	81	93
Tree coverage rate of enterprises (%)	7	19

3.32 The main products of the sector are ten metals—aluminum, copper, lead, zinc, nickel, tin, antimony, mercury, magnesium, titanium—and their alloys in various types of formed or shaped materials. Hundreds of other products and by-products are produced in small quantities, made from elements such as tungsten, cobalt, molybdenum, bismuth, cadmium, rare earth metals and rare metals. The sector also produces sulphuric acid, cement and carbon products. China ranks sixth in the world for production of nonferrous metals.

3.33 The present production capacity is about 3 million tons of metals per year. Those produced in the largest quantities are aluminum, copper, lead and zinc: together, these make up over 90 percent of the output of the ten metals and their manufacture takes about 80 percent of the energy for the whole nonferrous industry. In 1990, 2.5 million tons of nonferrous metals were produced, including 2.26 million tons of copper, aluminum, lead and zinc. Recent statistics are as follows:

	1985	1989	1990	Capacity
Operating enterprises	747	894	917	-
Construction, prospecting	73	56	54	-
Universities, schools	125	172	186	-
Total	945	1,122	1,157	-
Employment (millions)	1.26	1.35	1.37	-
Main products (million tons)				
Copper	0.413	0.562	0.559	0.60
Aluminum	0.525	0.758	0.854	1.20
Lead	0.225	0.302	0.297	0.40
Zinc	0.306	0.451	0.552	0.55
Total	1.469	2.073	2.262	2.75
Energy consumptions (10^6 TCE)				
For 4 major metals	-	-	14.91	
For 10 metals	13.63	17.52	18.14	
For entire sector	-	-	18.91	

3.34 Aluminum is produced from bauxite by the Bayer process or by a sintering process, or by a combination of the two. Chinese bauxite is usually the monohydrate type. The industry includes 65 smelters and aluminum oxide plants of which 12 major plants are situated in the cities of Fushun, Zhengzhou, Guiyang, Lanzhou, Xinin and Baotou, in the Ningxia Autonomous region and in Shanxi Province. Plant capacities vary from 30,000 to 100,000 tpy electrolytic aluminum: almost all facilities were constructed in the 1950s and 1960s.

3.35 The copper industry is based mainly on the processing of sulphide ores containing 0.5 to 2.0 percent copper. Operations include ore crushing and milling, followed by concentration in flotation processes to about 20-30 percent copper. The concentrates are dried, calcined or sintered in a variety of equipment to produce crude copper, which is further refined by the electrolytic process. There are 120 mines and smelters, of which 9 major plants are located in the cities of Baiyin, Tonglin, Shenyang, Kunming, Shanghai, and in the provinces of Hubei, Shanxi, Jiangxi and Guangdong. These have capacities from 20,000 to 70,000 tpy of copper. Most were built in the 1950s and 1960s and many have operated 30 years or more.

3.36 There are about 200 lead and zinc mines and smelters with capacities from 10,000 to 16,000 tpy, most at least 25 years old. The main plants—about 16—are in Zhuzhou, Shaogang, Shenyang, Baiyin, Jingxi and Changsha. The basic processes include sintering and smelting in blast furnaces.

3.37 Copper, aluminum, lead and zinc, and materials made from these metals, are sold mainly on the domestic market. For example, in 1990 only about 3 percent copper, 8 percent aluminum, 15 percent lead and 10 percent zinc were exported although much of the production can meet the highest international specifications.

Energy Use

3.38 In 1990, the industry consumed in total 18.91 million TCE of which about 13 million TCE or 70 percent were used by state-owned enterprises and 5.14 million TCE or 30 percent by local and TVE operations. For the 10 main metals, consumption was 18.41 million TCE. The nonferrous sector consumes about 1.9 percent of the national energy demand.

3.39 Energy use in 1990—including TVE plants—for manufacture of the 10 main metals and related products was as follows:

	Elec. 10^9 kWh	Coal 10^3 t	Coke 10^3 t	Oil 10^3 t	Nat. gas 10^6 m^3	Total 10^6 TCE
10 major nonferrous metals	25.46	7,360	1,008	734	70.74	18.14
of which: Copper	3.38	1,011	303	231	48.78	2.70
Aluminum	15.10	3,562	189	275	0.35	9.76
Lead, zinc	0.21	1,320	311	46	0.00	2.18
Percent based on TCE /a	56.7	29.0	5.4	5.8	0.5	100.0

/a Other energy sources, not specified, 2.6 percent.

3.40 The 1990 energy consumption for the 10 metals may be broken down into that used for national and local enterprises as follows:

	Quantity 10^6 TCE	Percent
National plants	13.00	71.7
Local (TVEs)	5.14	28.3
Total	18.14	100.0

3.41 The total energy consumption is equivalent to 2.7 TCE per Y 10,000 output value and 6.8 TCE per ton of nonferrous metal on average. The manufacture of one ton of nonferrous metal consumed on average 10,650 kWh of electricity, 3.08 tons of coal, 0.42 tons of coke and 0.22 tons of oil. The highest energy consumption was for aluminum manufacture, mostly for smelting. For the manufacture of copper, mining operations took 70 percent and smelter operation 30 percent. Further data on energy consumption from 1980 to 1990 are given in Table 3.21.

Table 3.21: ENERGY CONSUMPTION OF NONFERROUS ENTERPRISES, 1980-90

		1980		1985		1990	
		Qty	%	Qty	%	Qty	%
Whole Industry:							
Electricity	10^9 kWh	15.43	57.11	19.43	57.61	25.46	56.70
Coal	10^3 t	4350	28.45	5302	27.78	7360	28.97
Coke	10^3 t	576	5.12	900	6.41	1008	5.39
Fuel oil	10^3 t	530	6.93	731	7.66	734	5.78
Natural gas	10^6 m^3	36.0	0.44	32.7	0.32	70.74	0.51
Others			1.95		0.22		2.65
Total	10^6 TCE	10.92	100.0	13.63	100.0	18.14	100.0
of which:							
Consumption by state-owned enterprises	10^6 TCE	7.90	72.37	10.10	74.12	13.00	71.66
Consumption by local ent.	10^6 TCE	3.02	27.63	3.53	25.88	5.14	28.34

3.42 Estimates of the end uses of energy were made for 1990 operations and these are shown in Table 3.22. About half the coal was used for electricity generation and 60 percent of the electricity for electrolysis.

3.43 With respect to process energy use, several major technologies are applied in this sector. For example, the production of copper consists of three basic stages—primary smelting, refining and electrolysis. The second and third stages are much the same for all plants but the first stage may be carried out in a blast furnace, an electric furnace, a flash furnace or a reverberatory furnace, with quite different energy consumptions (see Table 3.23). The production processes for the other major metals are also quite diverse: some typical energy consumption data are given in Table 3.24.

3.44 With respect to coal supplies, about one seventh of energy is purchased at a negotiated market price and the remainder at the price set by the plan (which is about Y 50 per ton less expensive). About 90 percent of the coke demand is supplied by the plan at a price Y 80 to 100 cheaper than the open market price. In 1990, about 80 percent of oil needs were supplied on the plan at Y 150/t, and the remaining 20 percent was purchased at Y 320 to 350/t above that.

Energy Efficiency

3.45 The energy efficiency of nonferrous metal manufacture is not as good in China as in many advanced countries for various reasons, including:

(a) Relatively poor resources and lower ore grades result in additional energy consumption in mining and processing.

(b) Backward production technologies and equipment require higher energy inputs.

(c) In recent years, funds for capital investment and technical transformation have been used primarily to increase production, with relatively little used for energy saving investments.

(d) Some processing plants carrying out trial production runs—either as new plants or after technical modifications—consume more than normal quantities of energy.

3.46 Information on the efficiency of major items of equipment was collected for 1990 operations and is presented in Table 3.25 for boilers and gas generators and Table 3.23 for furnaces and kilns. The combustion efficiency of the smallest boilers was 50 percent and of the largest 85 percent. Furnace efficiencies are often quite low and suggest potential for improvement through modernization and replacement of the oldest and least efficient items.

Table 3.22: END USES OF MAJOR ENERGY SOURCES, 1990

	Unit	Quantity	Percent
Coal:			
Electricity generation, gas supply	10^6 t	3.50	48.0
Fuel and reductant	10^6 t	3.20	43.0
Gas generation	10^6 t	0.50	6.8
Other uses	10^6 t	0.16	2.2
Total	10^6 t	7.36	100.0
Coke:			
Fuel and reductant	10^6 t	0.85	85.0
Gas generation	10^6 t	0.15	15.0
Total	10^6 t	1.00	100.0
Fuel oil			
Fuel and reductant	10^6 t	0.47	88.0
Boiler fuel	10^6 t	0.06	12.0
Total	10^6 t	0.53	100.0
Electricity:			
Electrolysis of aluminum, copper, lead, zinc	10^9 kWh	14.6	57.5
Electric furnaces, heating	10^9 kWh	1.2	4.7
Motor drives	10^9 kWh	8.0	31.5
Other	10^9 kWh	1.6	6.3
Total	10^9 kWh	25.4	100.0
Steam:			
Electricity generation, steam supply	10^6 t	13.50	60.0
Heating industrial buildings	10^6 t	2.00	8.9
Metallurgical processes	10^6 t	15.70	69.8
Total /a	10^6 t	22.50	100.0

/a Note that steam for electricity generation and steam used for production processes are partially double-counted, thus the total do not add to 100 percent.

Table 3.23: TYPICAL FURNACES AND KILNS AND THEIR EFFICIENCY

No.	Equipment	Size and capacity	Piece	Heat efficiency (%)
1.	Aluminum electrolytic cell	Prebaked & top or side conduct. Baked		
2.	Copper electrolytic cell		7,000	
3.	Lead electrolytic cell		9,000	
4.	Zinc electrolytic cell			
5.	Sintering machine	20 to 100 m^2	9	
6.	Boiling furnace	2.5 to 42 m^2	30	45 to 50
7.	Copper blast furnace	5.3 to 12.6 m^2	9	50 to 55
8.	Copper reverberatory furnace	12 to 270 m^2	15	15 to 25/a 25 to 30/b
9.	Copper, nickel, and tin converter	5 to 50 t	35	35 to 50
10.	Lead blast furnace	2.5 to 8 m^2	5	50 to 55
11.	Lead & zinc closed blast furnace	YS2010	2	70
12.	Copper & nickel smelting electric furnace	12,000 to 30,000 kVA	6	60 to 70
13.	Concentrate calcining kiln	Φ1.6 to 2.6 m	19	55 to 65
14.	Slag volatilizing kiln	Φ1.5 to 2.4 m	8	20
15.	Aluminum oxide grog kiln	Φ3.6 to 4.5 m	17	60 to 65
16.	Aluminum oxide calcining kiln	Φ2.6 to 4.0 m	15	50 to 55
17.	Cement kiln	Φ1.5 to 4.5 m	35	60
18.	Lime kiln	Φ3.0 to 4.0 m	8	75 to 80
19.	Carbon. element calcining furnace	12 to 24 chambers	12	
20.	Carbon. element rotary kiln	Φ2.0 to 2.5 m	4	
21.	Zinc distilling furnace		24	35 to 40
22.	Zinc rectifying furnace		21	35 to 45

/a Refining.
/b Smelting.

Energy Efficiency Trends

3.47 Efforts have been made since the early 1980s to reduce energy consumption by process renovation, equipment modernization and the utilization of new technologies. In the mining area, improved methods and equipment have been adopted and large-scale mining in open pits is used in several new mines. Other changes include the use of electricity in place of compressed air for underground drilling, and using more efficient vehicles for underground mining and transportation. Crushing and milling operations have been improved also, modified flotation cells are used for ore concentration, and autopress

Table 3.24: SPECIFIC ENERGY CONSUMPTIONS FOR SELECTED PROCESSES

No.	Tech. name of products	Unit	1980	1985	1990
1.	Aluminum oxide produced by caulking	TCE/t	-	1.60	2.00
2.	Aluminum oxide produced by combination process	TCE/t	-	1.26	1.50
3.	Aluminum oxide produced by byaer method	TCE/t	-	-	0.90
4.	Electrolytic aluminum produced in precalcining cell	DC kWh/t	-	-	14,450
5.	Electrolytic aluminum produced in upper insert cell	DC kWh/t	-	-	15,800
6.	Electrolytic aluminum produced in side insert cell	DC kWh/t	-	-	14,850
7.	Crude copper from flash furnace	TCE/t	-	-	0.78
8.	Crude copper from electric furnace	TCE/t	-	-	0.98
9.	Crude copper from blast furnace	TCE/t	-	-	1.26
10.	Crude copper from reverberatory furnace	TCE/t	-	-	1.30
11.	Lead from sintering blast furnace	TCE/t	-	-	0.80
12.	Lead from closed blast furnace	TCE/t	-	-	0.84
13.	Zinc from closed blast furnace	TCE/t	-	-	0.45
14.	Zinc produced by hydrometallurgical proc.	TCE/t	-	-	2.22
15.	Zinc from vertical retort.	TCE/t	-	-	2.70

filters used instead of vacuum filters to remove water from concentrates before further processing. As a result, energy consumption per ton of contained copper in copper concentrates has dropped from 5.8 TCE/t in 1980 to 4.0 TCE/t in 1990 in spite of the gradual decrease in ore grade and deeper mining.

3.48 For copper smelting, various measures have been adopted. These include modern flash furnaces, adding oxygen rich air blowing to older furnaces to increase capacity and reduce coke rate, utilizing waste heat from high temperature combustion gases of reverberatory furnaces to raise steam for electricity generation, and reforming the design of such furnaces and adding automatic controls to reduce energy consumption by about 50 percent. Consumption in copper smelting has dropped from 2.4 to 1.95 TCE/t from 1980 to 1990.

3.49 In the processing of aluminum, aluminum oxide plants have been renovated, calcining kilns modified, the silicon removal process improved and flash calcining adopted in place of rotary kilns. Statistics on the energy consumption of the industry indicate an

Table 3.25: CAPACITY AND EFFICIENCY OF MAJOR EQUIPMENT, 1990

No.	Equipment	Size	Pieces	Heat efficiency (%)	Heat vapor (Y, t/h)
	Boiler		1,520	8,000	
1.	Coal-powder boiler	130 t/h	13	85	1,690
2.	Coal-powder boiler	75 t/h	18	85	1,350
3.	Coal-powder boiler	50-60 t/h	5	82	260
4.	Coal boiler	35 t/h	11	76	385
5.	Coal boiler	20 t/h	26	72	520
6.	Coal boiler	10 t/h	35	70	350
7.	Coal boiler	6 y/h	(60)	65	(360)
8.	Coal boiler	4 t/h	(200)	60	(800)
9.	Coal boiler	2 t/h	(350)	55	(700)
10.	Coal boiler	<2 t/h	(800)	50	(1,500)
	Gas Generator		(60)	70 avg.	
1.	Gas generator	Φ3 m	(50)	72	
2.	Gas generator	<Φ 3 m	(10)	68-70	

increase in energy use, however, as more energy is used in processing while modified plants are brought on line.

3.50 Energy saving measures adopted in electrolytic aluminum refining plants include using larger cells while shutting down the smallest cells, improving rectifier efficiencies to save about 300 kWh/t aluminum, and applying a number of other measures such as microcomputer controls, adding lithium salts to the electrolyte, and using improved cathodes, the latter saving about 400 kWh/t.

3.51 In the production of lead and zinc, improvements include using modern imported technologies for lead smelting, increased use of waste heat from smelters, installation of waste heat boilers on calcining and distilling furnaces, use of this steam for electricity generation, reconstruction of zinc redistilling furnaces, and elimination of outdated zinc smelters.

3.52 The overall results of adopting a wide range of energy efficiency measures and emphasizing good energy management has been estimated as a saving of 1.5 million TCE in the period 1980 to 1990, representing an average of 1.5 percent per year. Industry output has increased by 90 percent while energy use has grown 70 percent. Data for operations from 1980 to 1990 indicate relative energy consumptions and trends in unit energy use:

(TCE/t metal)	1980	1985	1990
Average unit consumption for 10 metals	7.26	6.65	6.80
Manufacture of aluminum oxide	-	1.61	1.95/a
Aluminum ingot	-	7.34	7.20
Copper smelting	2.40	2.10	1.90
Lead smelting	-	-	0.80
Zinc smelting	-	-	2.80

/a Energy consumption raised due to switch to oil from coal and non standard operations.

Potential for Improvement

3.53 Technological changes in nonferrous metal processing and increased demand will result in many new plants being built and old plants modernized. With respect to the copper industry, about 550,000 tons were produced in 1990, consuming 1.1 TCE/t, out of a capacity of 600,000 tpy crude copper. By 2000, it is expected that capacity will have risen to between 750 and 850,000 tpy. The total capacity of flash smelting will be double that of 1990 and the capacity of new and rebuilt bath smelters will be 450,000 tpy. Electric furnace capacity will be maintained but blast furnace capacity reduced to 15,000 tpy. The overall energy consumption is expected to fall to 0.8 TCE/t of copper. By 2010, capacity should be 950,000 tpy and energy consumption say 0.6 TCE/t.

3.54 With respect to lead, capacity in 1990 was about 400,000 tpy although actual production was only 297,000 tons with an average consumption of 0.8 TCE/t of crude lead. By 2000, it is expected that capacity will be 600,000 tpy. The main purpose of plant modernization will be to improve environmental conditions rather than save energy. Energy consumption is expected to drop to about 0.6 TCE/t. By 2010, capacity should reach 750,000 tpy and energy consumption 0.5 TCE/t.

3.55 Zinc smelting capacity in 1990 was about 550,000 tpy and output was equal to this: energy consumption was 2.5 TCE/t. By 2000, capacity is expected to be 800,000 tpy. The modern ISP technology is expected to rise from 70,000 to 150,000 tpy capacity. Vertical vat smelting capacity will remain at 180,000 tpy and hydrometallurgical process capacity will rise from 300,000 to 500,000 tpy. Energy consumption per ton of refined zinc should be reduced by about 20 percent. By 2010, capacity should reach 1,240,000 tpy and energy consumption 1.8 TCE/t.

3.56 Regarding aluminum manufacture, ore properties have led to aluminum oxide being produced mainly by a combination process. The Bayer method will be adopted increasingly and direct heating methods replaced by indirect heating. Flash smelting, improved calcining, continuous silicon removal, and modernization of existing evaporators will also contribute to energy efficiency. In 1990, capacity for aluminum oxide manufacture was 1.7 million tpy and actual production 1.5 million tons, of which 45 percent was made by calcining and 55 percent by the combination process. Overall energy use was 1.7 TCE/t. By 2000, alumina output could reach 4.5 million tons of which 16 percent would be made by the Bayer process, 12 percent in the calcining process and 72 percent in a combination process. An energy consumption of 1.1 to 1.2 TCE/t is anticipated. By 2010, capacity should reach 5.5 million tpy of alumina with energy consumption 0.9 to 1.0 TCE/t.

3.57 With respect to electrolytic refining of aluminum, capacity in 1990 was 1.2 million tpy. Actual output was almost 0.9 million tons, of which 20 percent came from prebaked anode cells, 7 percent from top insert autobaked anode cells and the balance from side insert autobaked anode cells. Each ton of aluminum ingot consumed on average 6.8 TCE. By 2000, capacity should be 2.2 million tpy with the output from prebaked anode cells doubled compared with today's level. Emphasis will be placed on improved operation of large prebaked anode cells and the small side insert cells (power rating under 60 kA) will be eliminated. Medium-scale side insert cells will be fitted with computer controls for the cathodes. Average energy consumption is expected to decrease to 6.5 TCE/t. By 2010, capacity should be 3 million tpy electrolytic aluminum.

3.58 A summary of forecasts for capacities and energy use of various processes is given in Table 3.26.

Projected Industry Outputs and Energy Consumption

3.59 Indications of trends in processes and plant capacities are given above. The output of 10 nonferrous metals will be about 4.4 million tons by 2000 and 6.0 million tons by 2010. The expected energy consumption will be as follows:

	Production 10^6 tpy		Spec. cons. TCE/ton		Total cons. 10^6 TCE	
	2000	2010	2000	2010	2000	2010
4 major metals:						
Copper	0.80	0.95	5.33	5.33	4.26	5.06
Aluminum	2.10	3.00	10.00	9.50	21.00	28.50
Lead	0.50	0.60	1.70	1.67	0.85	1.00
Zinc	0.80	1.24	3.10	3.00	2.48	3.72
10 nonferrous metals	4.40	6.00	6.50	6.40	28.60	38.29
Complete sector					33.65	44.01

Table 3.26: FORECASTS OF PROCESS CAPACITIES AND SPECIFIC ENERGY CONSUMPTIONS FOR COPPER, ALUMINUM, LEAD AND ZINC PRODUCTION

No.	Process	1980		1985		1990	
		Capac. 10^4 t	Energy consump. TCE/t	Capac. 10^4 t	Energy consump. TCE/t	Capac. 10^4 t	Energy consump. TCE/t
Cu.	**Smelt**						
1.	Flash furnace	9.00	0.76	30.00	0.60	30.0	0.50
2.	Bath smelting	0.00	-	45.00	0.70	45.0	0.80
3.	Elect. furnace	7.00	0.98	7.00	0.95	7.0	0.85
4.	Blast furnace	12.50	0.90	1.50	0.90	1.5	0.30
Lead Smelting							
1.	Blast furnace	38.50	0.78	23.00	0.70	23.0	0.60
2.	I.S.P.	4.20	0.84	8.00	0.70	8.0	0.60
3.	Q.S.L. S.K.S	-	-	23.00	0.55	25.0	0.50
Zinc Smelting							
1.	Wet-smelting	30.00	2.22	50.00	2.00	50.0	1.80
2.	I.S.P.	7.00	2.45	15.00	2.00	21.0	1.80
3.	Vertical retort	22.00	2.67	18.00	2.20	20.0	2.00
Aluminum Oxide							
1.	Bayer	-	-	70.00	0.70	90.0	0.60
2.	Sintering	70.00	2.00	60.00	1.60	70.0	1.55
3.	Combination & connection	80.00	1.50	320.00	1.10	400.0	0.98
Aluminum Electrolysis							
1.	Upper-insert cell	6.00	7.00	3.00	6.80	8.0	6.35
2.	Precalcining cell	19.00	8.52	100.00	6.20	100.0	5.85
3.	Side-insert cell	60.00	6.80	93.00	6.50	120.0	5.85

3.60 The projected breakdown of energy consumptions for manufacture of the 10 metals is as follows:

	Unit	1990	2000	2010
Coal	10^3 t	7,360	11,200	15,900
Coke	10^3 t	1,008	1,260	2,100
Electricity	10^9 kWh	25.46	42.30	59.40
Fuel oil	10^3 t	734	800	1,200
Natural gas	10^6 m^3	70.74	11.42	16.20
Petroleum coke	10^3 t	0	670	1,030
Other	10^3 t	200	340	500
Total	10^6 TCE	18.14	28.60	38.29

Generic Investment Options

3.61 A measure contributing to energy efficiency which has good replication potential in the aluminum industry is the renovation of alumina sintering kilns (Case Study M5). This involves replacing old inefficient kilns with a modern flash drying and preheater kiln process, saving energy and increasing plant capacity. Actual plant data for this measure were obtained from the Shandong Aluminum Works. The internal rate of return was calculated to be 84.3 percent and the payback three years.

3.62 Based on the existing plant capacity in the industry of 6 million tpy which is considered to be appropriate for renovation in a similar manner, the following forecasts were made for "business as usual" and "accelerated" scenarios:

M5 aluminum plant renovation		1990	2000	2010
		(million tpy alumina)		
BAU	Unmodernized capacity	6.0	4.0	0.0
	Renovated capacity	0.0	2.0	6.0
Accel.	Unmodernized capacity	6.0	3.0	0.0
	Renovated capacity	0.0	3.0	6.0

3.63 Details of the assumptions made regarding future renovation of aluminum plants, together with energy consumption and emissions factors for both unmodernized and renovated plants, are given in Appendix A of this report.

Projected Impacts on Energy and Emissions

3.64 The expected impacts of aluminum plant renovation on the nonferrous sector energy use and emissions were calculated as follows:

	10^3 TCE/yr by 2000		10^3 TCE/yr by 2010	
	BAU	*Accel.*	*BAU*	*Accel.*
Energy savings	330	494	989	989
	10^3 t/yr by 2000		10^3 t/yr by 2010	
	BAU	*Accel.*	*BAU*	*Accel*
Reductions in CO_2 emissions	167	250	500	500

Emissions

3.65 The nonferrous metals sector includes many processes in which pollutant emissions occur, with the production of solid and liquid wastes and the release of atmospheric discharges, both dust and smoke. Because of the toxic nature of many of the metals and their compounds, emissions are always potentially hazardous. Data on typical emissions are given in Table 3.27.

3.66 Various measures have been taken to reduce pollution, so that emissions are now only slightly higher than in 1982 although annual output has doubled from 1.2 to nearly 2.4 million tons. These measures include the following:

(a) **Laws and Regulations.** Several major regulations have been introduced since 1984.

(b) **Personnel.** The numbers of environmental protection organizations and their staffing levels have been increased. These organizations are responsible for environmental management, monitoring and scientific studies.

(c) **Treatment of Sulphur Dioxide.** Increased quantities of sulphuric acid are now made from waste gases, resulting in the SO_2 emissions being held to 1982 levels. Several large acid production units have been commissioned, e.g., Jinchun Nickel Corp., Yunnan Smelting Co., Huludao Zinc Plant, Guixi smelting plant.

(d) **Fluorides.** Efforts have been made to reduce emissions of fluoride gases from aluminum electrolysis operations. Cleaning processes and equipment have been installed at plants in Guizhou, Qinghai, Baiyin, Lanzhou, Qingtongxia, Shandong and Liangchen. Annual discharges of fluorides have

Table 3.27: POLLUTANT DISCHARGES FROM TYPICAL PROCESSES

No.	Tech. name of products	Measure unit	1980	1985	1990	Differences from the inter. advanc. level
1.	Aluminum oxide products by calcining					
2.	Aluminum oxide products by series process					
3.	Aluminum oxide productions by bayer process					
4.	Aluminum reduction in prebaked anode cell	kg F/t Al	7.43	-	2.5-2.7	1
5.	Aluminum reduction in top-electroconductive auto-baked anode cell	kg F/t Al	20	20.00	20.00	
6.	Aluminum reduction in side-electroconductive auto-baked anode cell	kg F/t Al	14.5	14.86	15-20	
7.	Copper smelting in flash furnace	kg SO_2/t Cu	-	-	36.86	100-50 (ppm)
8.	Copper smelting in electric furnace	kg SO_2/t Cu	705	620	243.10	1
9.	Copper smelting in blast furnace	kg SO_2/t Cu	11,457	12,870	830	
10.	Copper smelting in closed blast furnace	kg SO_2/t Cu	9,211	8,245	10,422	
11.	Lead sintering & smelting in blast furnace	kg SO_2/t Pb	266	112	110	
12.	Lead smelting in closed blast furnace	kg SO_2/t Pb	32	31.8	30.66	
13.	Zinc smelting in vertical retort	kg SO_2/t Cu	38	31.89	30.00	
14.	Zinc wet smelting	kg SO_2/t Cu	230	222.87	200	

been reduced by about half.

(e) **Wastewater.** Reuse ratios have been increased from about 50 to 66 percent and discharges cleaned by the installation of new treatment plants. Water discharges meeting national standards are now up to 70 percent.

(f) **Particulates.** Emissions are still high and only 93 percent of discharges now meet required standards. Further investment in cleaning equipment is necessary.

(g) **Solid Wastes.** These are a serious problem and consist of about 60 million tons annually of a wide variety of materials such as tailings, red mud, slags, coal dust and ashes. Only about 8 percent is utilized.

(h) **Restoration of Tailings Reservoirs.** These contain about 1 billion tons of mine tailings and occupy over 8,000 hectares in addition to 400 hectares of agricultural land. The size is increasing each year. At ten enterprises, restoration has begun with planting and sowing, and some reuse of land for agriculture has been achieved—e.g., at Zhongtiaoshan mines, Xiaoguan bauxite mine, Yangjiazhangzi mines, Hongtoushan copper mines, Yunnan tin mines, and Xihuachan and Pangushan tungsten mines.

3.67 Overall, in the five years from 1985 to 1990, Y 660 million were spent on 2,743 environmental protection projects, including 888 relating to wastewater, 817 to gaseous emissions, 256 to waste slags, 282 to noise suppression, and 300 to a variety of other items.

3.68 In the next few years, even greater efforts will be needed to reduce pollutant emissions and clean up contaminated areas. Specific projects have been identified for completion but many are behind schedule, mainly due to lack of funds. These projects and many other smaller-scale measures should bring discharges of all the main pollutants, excluding fluoride-containing gases of some aluminum plants, under good control by 1995. Although industry output is increasing, the quantities of pollutants should remain about the same. By 2000, further pollutant control will be established and it is expected that at least 90 percent of emissions will reach national standards.

C. Building Materials

Industry Profile and Products

3.69 The building material subsector includes manufacture of construction materials, nonmetallic mineral products and inorganic materials. The sector covers over one thousand products, made by more than 63,000 enterprises (both state and collectively owned, but excluding rural enterprises) employing around 10 million personnel, with a total output value of Y 97 billion. There are about 400 large-scale key enterprises.

3.70 The main products of the industry are cement, flat glass, ceramics, bricks, tiles and lime. China has become the largest producer in the world of most of these products. Processes include sintering, firing and drying in kilns or furnaces, in which fuel consumption is often high and emissions of CO_2 and other pollutants are large. Production quantities in 1990 and 1991 were as follows:

		1990	1991
Cement	106 tons	209.70	252.61
Flat glass	106 cases /a	80.67	87.12
Sanitary ware	106 pieces /b	-	18.90
Floor and wall tiles	106 m^2	-	2.27
Bricks	109 pieces /c	448.50	456.00
Roofing tiles	109 pieces /d	48.20	49.40
Lime	106 tons	93.79	106.78

/a 1 case = 50 kg.
/b 1 piece = 9 to 9.5 kg.
/c 1 standard brick is 240 x 115 x 53 mm.
/d 1 standard tile is 400 x 240 mm, thickness 10-17 mm.

3.71 With respect to cement, current capacity is 294 million tpy: the production of 252.6 million tons in 1991 puts China into first place in the world. Cement plants may be divided into two categories—large/medium-size cement plants and small-scale plants serving localized markets. There are 68 enterprises with large/medium-scale plants—average output 535,000 tpy—all using rotary kilns (total 208, of which 108 use the wet process) and with a total output of 36.8 million tons in 1990. Medium and small-scale plants down to county level—average output 62,000 tpy—produced 130 million tons and small-scale rural plants (TVEs, average output 13,000 tpy) contributed about 43 million tons.

3.72 Large/medium-scale plants use a variety of different technologies. Some plants have the latest precalciner systems, while others are still using the technologies of the 1920s or 1930s. For example, of the large/medium-size state-owned plants, 29 were built before 1950 and most of these have undergone renovation and reform since 1986. In terms of production methods, the following breakdown has been estimated:

	Percent of capacity /a	Average fuel use kgCE/t clinker
Total clinker production	100	190
Rotary kilns	29	199
of which, wet process	11	210
Lepol kilns	2.5	160
dry process	16.5	185
of which, precalciner	4.5	105
standard dry process	4	285
with waste heat boiler	3	180
with cyclone preheater	2.5	120
with shaft preheater	2	138
Shaft kilns	71	186
of which, mechanized	60	165
ordinary shaft kilns	11	250
indigenous kilns	1	330

/a Some minor discrepancies due to rounding.

3.73 Some of the precalciner kilns have only recently been commissioned and their output remains under full capacity. There are 16 production lines and their output was 8.44 million tons in 1990.

3.74 There are over 5,000 small-scale cement plants of which 400 are using small rotary kilns and the remainder use vertical shaft kilns. As indicated above, most cement is made in shaft kilns. Of the small-scale enterprises, around 3,000 use mechanized shaft kilns but almost 2,000 enterprises still use backward types of shaft kiln with no guarantee of cement quality and whose energy consumption is often high. These kilns are expected to be eliminated eventually but will remain an important means of production for many years.

3.75 With respect to flat glass, there are more than 130 furnaces with a capacity of 99.25 million cases. Within these, there are 23 float glass production lines, making about 40 percent of the glass output. Of the actual production of 80.67 million cases in 1990, 71.65 million were manufactured by large and medium-scale enterprises, almost 90 percent of the national output. There are three main production technologies employed: float glass, vertical draw and horizontal draw furnaces. Current production (1991) is predominantly from the first two types:

Type of furnace	Number of furnaces	Est. output mill. cases	Typical size tons
Float	23	32.3 (40%)	300-700
Vertical	71	40.3 (50%)	<300
Horizontal	42	8.1 (10%)	small

3.76 The float glass furnaces were built mostly in the late 1970s and achieve high quality production, while the vertical draw furnaces date from the 1950s and quality is lower. The horizontal draw furnaces are at a much lower technical level and are quite small: quality is often poor.

3.77 The ceramics categories include sanitary ware, floor and wall tiles. In 1991, there were 18.9 million pieces of sanitary ware made with a total weight of 0.17 million tons. Tile production was 1.23 million m^2 of glazed wall tiles and 1.04 million m^2 of floor tiles, making the total output 2.77 million m^2, the largest in the world. Currently there are over 1,000 continuous firing kilns in 797 ceramics enterprises in China, of which 13 are considered key enterprises with an output of 3.4 million pieces of sanitary ware, 0.1 million m^2 of glazed wall tiles and 0.035 million m^2 of floor tiles. The larger plants use tunnel and roller hearth kilns. Most of the remaining production is carried out in over 800 kilns by small-scale enterprises with older equipment. Product quality varies considerably, with the newer larger plants producing higher quality items for hotel construction, for example, and for export. Production from the large number of small-scale enterprises is often poor quality and is tolerated in the marketplace as demand is so high.

3.78 The clay brick and tile industries represent about one quarter of the total output value and 40 percent of the energy consumption of the building materials sector. In 1990, the production of bricks reached 448.5 billion standard bricks and of roofing tiles, 48.2 billion pieces. Brick production was divided as follows:

3.79 This shows that brick production is dominated by the TVEs. Most of these operate small plants, although plant size is increasing and a number of brick kilns with capacity over 50 million bricks per year are now operated by TVEs. Tile production is also dominated by the TVEs who represent over 90 percent of the national output. In 1990, about 4.6 billion tiles were made by state-owned plants. In the clay brick and tile industry, the competition provided by TVE plants is particularly strong,assisted by such factors as the following:

Type/number of enterprises	10^9 Bricks	Avg size 10^6/yr
Large/medium plants (11)	1.4	127
County and above (about 1,800)	78.0	43
Small TVE plants (over 90,000)	369.1	4
Total	448.5	

(a) Favorable tax treatment.

(b) No fees for clay utilization as TVE plants use "their own" land, mostly in agricultural areas.

(c) There are no welfare facilities for personnel.

(d) Managerial costs are lower.

(e) Pensions are not provided.

3.80 The ability of state-owned plants to compete is thus restricted and it is estimated that about 10-15 percent of state-owned brick and tile capacity has been shut down in recent years.

3.81 China is a major producer of lime, the output being 93.79 million tons in 1990 and coal consumption 10.5 million TCE. There are about 5,000 enterprises making lime in China, with 85 percent operated by TVEs. The lime industry is very backward: many of the plants operate primitive equipment manually and make a low quality product. Mechanized shaft kilns are used in most state enterprises, with various types installed.

Energy Use

3.82 The total energy consumption of the building material industry, including TVEs, amounted to 119.1 million TCE in 1990, about 12 percent of the national energy demand. Energy consumptions were:

Coal	102.1	10^6 TCE
Electricity	33.2	10^9 kWh
Oil fuels	2.5	10^6 tons
Total	119.1	10^6 TCE

A small amount of natural gas is also used but no consumption data are available. Including related activities, energy consumption for producing building materials was 122.91 million TCE.

3.83 Energy consumptions for different types of product were as follows:

	Energy use, 10^6 TCE	Percent
Bricks, tiles	54.37	45.7
Cement	40.71	34.2
Lime	10.48	8.8
Flat glass	3.13	2.6
All other	10.41	8.7
Total	119.10	100.0

Specific Energy Consumption

Cement

3.84 Although there are some modern cement kilns operating at high efficiency in China, the typical energy efficiencies of manufacturing processes lag behind comparable plants in advanced countries. For example, the following figures may be quoted:

	Domestic industry energy use kgCE/t clinker	Typical foreign plant energy use kgCE/t clinker
Wet process kiln	180-230	180
Dry process kiln	140-180	115
Preheater kiln	110-165	105
Precalciner kiln	100-125	100
Vertical shaft kiln	100-250	98

3.85 The average fuel consumption for the cement industry in 1990 was almost 190 kgCE/t of clinker produced: the average electricity consumption is 99 kWh/t cement.

Flat Glass

3.86 The specific energy consumptions of the three main categories of glass furnace vary considerably between enterprises, with large plants usually more efficient than small ones. The float glass process is more energy efficient, typically consuming fuels and electricity equivalent to about 29 kg standard coal per case (0.58 TCE/t), large vertical furnaces about 33 kg (0.66 TCE/t), small vertical furnaces about 40 kg (0.8 TCE/t), and horizontal furnaces around 50 kg (1 TCE/t). In general terms, the energy consumption for manufacture of flat glass in China is about twice the level for advanced foreign countries, partly due to the small scale and also to the age of equipment and backward technology employed.

Ceramics

3.87 The ceramic industries consumed 3.74 million TCE in 1991 (almost 3 percent of the building materials sector). Specific energy consumption amounts to 1.8 TCE/t for sanitary ware. For glazed tiles, energy consumption is 12.5 $kgCE/m^2$ and for floor tiles, 10.5 $kgCE/m^2$. These figures are high compared with advanced countries, especially for tiles where the consumption is often at levels of 2-3 $kgCE/m^2$.

Clay Bricks and Tiles

3.88 The larger state-owned enterprises mostly use tunnel kilns and Hoffman type annular kilns, with energy consumptions in the region of 0.8 to 1 TCE per 10,000 bricks. Most plants operate continuously over a long time. Some tunnel kilns operate with full artificial drying, utilizing waste heat from the kiln combustion gases together with a small amount of supplementary firing. The smaller TVE plants also reach energy consumption figures of about 1 TCE/10,000 bricks, operating annular or Hoffman type brick kilns which are in almost universal use in the countryside.

3.89 Currently, many brick plants mix coal ash or coal dust with the raw materials before firing. In the brick kiln, the energy is released through "internal firing", reducing the amount of fuel added to the kiln separately. In extreme cases, there is no need to fire any coal separately and all the energy can be derived from wastes and low grade coals. More often, the amount of high grade coal fired in the kiln is reduced to say 200-300 kgCE/10,000 bricks.

Lime

3.90 The lime industry in China remains relatively backward and energy efficiency is low. Typical coal use by small and old kilns is 180 kgCE/ton, and by mechanized shaft kilns say 135 kgCE/ton. As the basic process is simple, energy costs are a high proportion of total costs, around 50-60 percent, with large kilns usually the most efficient. There are mechanical vertical kilns with capacities of 30, 60, 90, 125 and 200 tpd in common use in the industry.

Energy Efficiency Trends

3.91 Data indicating trends in energy consumption for the building material industry are given in Table 3.28. These show an overall decrease in energy use amounting to about 3 percent per year from 1980 to 1990. The estimated saving in energy use amounts to almost 27 million TCE over the period 1980 to 1990 and this has been achieved by a wide range of measures in each part of the industry, such as better management, waste heat recovery, and adoption of more up to date equipment.

3.92 Energy consumption for cement manufacture has improved steadily. Figures for total energy consumption, including electricity, for the last 10 years are as follows:

	kgCE/t/t-clinker
1980	208.8
1981	206.0
1982	206.9
1983	204.8
1984	211.3
1985	208.1
1986	207.6
1987	202.3
1988	199.8
1989	200.4
1990	189.9

Table 3.28: Historical Data on Energy Consumption Data for the Building Materials Industry

	TCE per 10,000 yuan output	Energy saving % per year	Estimated energy saving, 10_6 TCE
1980	27.26	-	-
1981	26.09	4.29	2.28
1982	26.20	0.42	0.25
1983	24.87	5.08	3.26
1984	25.41	-2.17	-1.55
1985	23.87	6.06	5.40
1986	24.08	-0.92	-0.88
1987	23.04	4.36	4.69
1988	22.89	2.82	3.38
1989	21.42	4.33	5.39
1990	21.23	0.88	4.38

Note: Data calculated on the basis of constant 1980 yuan.

3.93 These results have been achieved in a number of ways. Low efficiency plants have been shut down: for example, over 1,100 small-scale plants were closed after 1980. More use has been made of higher efficiency imported technology, such as dry process precalciner equipment from Japan, roller mills from Germany, raw meal homogenization equipment from Germany and Denmark, and grate coolers from the USA.

3.94 Energy efficiency data for the manufacture of flat glass show little improvement has been achieved since 1980:

Year	Unit energy consumption kgCE/case	Unit energy consumption TCE/ton
1980	32.1	0.642
1981	32.2	0.644
1982	32.1	0.642
1983	31.5	0.630
1984	31.9	0.638
1985	32.9	0.658
1986	33.1	0.662
1987	35.4	0.708
1988	34.5	0.690
1989	31.4	0.628
1990	31.5	0.630

3.95 In the clay brick and tile industries, there has been a steady improvement in the energy use per unit of output. The performance of state-owned brick enterprises has shown a steady improvement as follows:

	Coal consumption kgCE/10,000 bricks
1983	1,180
1984	1,100
1985	955
1986	991
1987	933
1988	789
1989	834
1990	850

Potential for Improvement

Cement

3.96 The main type of kiln in use in large/medium-scale plants is the wet process kiln, of which there are about 108 (half the number of kilns in large/medium-size plants). Some of these were built in the 1940s but remain in operation. The wet process consumes more energy than the basic dry process, which itself has been improved by preheater and precalciner technologies. There is therefore a large potential for saving energy although the capital investment needed to upgrade cement manufacturing facilities will be substantial. There are four types of action needed:

(a) New installations, involving the replacement of old wet process kilns by preheater and precalciner kilns. About 26 production lines using precalciner technology have already been built in China, with daily capacities from 700 to 4,000 tons of clinker. The investment required is typically Y 150 million for a precalciner kiln making 1,000 tpd clinker.

(b) Conversion of wet process kilns to the semi-dry process. There are some pilot projects for this change (e.g., a semi-dry line with vacuum slurry filtration in Guangzhou). An investment of about Y 60 million is needed for modifications.

(c) Rehabilitation of electricity generation equipment on old kilns. There are several old kilns built before 1949 which could be upgraded to increase cement production by 15 percent and electricity production from 100 kWh to 150 kWh/ton of clinker. The capital investment ranges from Y 30 to 100 million per kiln. The economic viability of rehabilitation requires careful checking as electricity generation by waste heat has not been found economic in western cement plants.

(d) Improved operation of wet process kilns, to be achieved by a variety of smaller-scale measures. Energy consumption could be reduced from say 1,500 to 1,250 kcal/kg clinker by:

   (i) installation of chains in kilns
   (ii) use of higher heat resistant refractories
   (iii) increased use of slurry thinners
   (iv) coal burner modifications
   (v) coal grinding mill modifications

   A rough estimate of the investment per kiln is Y 5 million.

3.97 In the case of small-scale rotary kilns, some of these could be modified with the installation of 4 or 5 stage preheaters: a typical kiln—diameter 1.5 to 2 meters, capacity 140-160 t/d—needs Y 18 million investment. Some small kilns with poor efficiency may be shut down.

3.98 With respect to shaft kilns, although these often show reasonably good energy efficiency, there are problems of maintaining good clinker quality. However, over the last ten years or so, various measures—including computer control—have been developed and applied to shaft kilns to reduce energy consumption and improve clinker quality. Experience in several plants shows that kiln fuel consumption can be reduced to 120 kgCE/t clinker (840 kcal/kg), which is close to the performance of a modern preheater kiln. Electricity use of 80-85 kWh/t cement is also achieved and this is a good performance. The cost of modifications varies for different plants but is typically Y 3 million. It is expected that around 3,000 mechanized shaft kilns will undergo progressive modifications and improvements over a period of several years. For the most primitive kilns, the best will be modified into mechanized kilns while many of the poorest ones will be shut down.

3.99 Lower energy consumption for clinker grinding is also a potential area for savings. Most of the current mills are low efficiency ball mills: total electricity use amounts to over 17,500 million kWh annually. Some measures to reduce this are:

(a) installation of higher efficiency vertical and roller mills,

(b) addition of pre-crushing stage and better air-separator,

(c) use of higher quality abrasion resistant grinding media,

(d) use of steel rods rather than balls, and

(e) elimination of ball mills under 1.8 m diameter.

3.100 Another area for significant energy saving is the increased application of industrial wastes for cement and concrete manufacture. Specifically, industrial slags, fly ash and natural pozzolans could be used in much greater quantities in conjunction with clinker to produce blended cements. Chinese cement specifications allow significant quantities of waste materials to be used:

for blast furnace slag cement	20-70 percent of slag
for pozzolan portland cement	20-40 percent pozzolans
for portland fly ash cement	20-40 percent fly ash

3.101 The current production level of these blended cements is only 5-6 million tons (of which 4 million tons are made by large/medium-scale enterprises) out of over 250 million tons of cement. The potential saving of clinker by increased production of these three types of blended cement is probably 15-20 million tons annually in the short term—say within five years—equivalent to coal savings of say 4 million tpy. Over the long term, say by 2010, savings could easily be doubled.

3.102 With respect to raw materials, coal shale and high carbon content fly ash are used in some plants to reduce overall coal consumption.

Flat Glass

3.103 Although the energy consumption of this industry is only 3.13 million TCE per year, about 2.6 percent of the energy used for building materials, the energy costs tend to be high due to the need for high quality fuels (e.g., heavy oil, low ash coals and natural gas). There is therefore strong interest in energy efficiency and various modifications to plants are being adopted:

(a) **Installation of Float Glass Furnaces.** At present, the technology for 500 tpd float glass production systems is imported from the USA at a cost of Y 350 million for a new installation and about Y 50 million for each revamp of an existing plant. The new system results in a decrease in energy consumption of almost 50 percent.

(b) Modifications to vertical and horizontal draw furnaces—various techniques and improvements have been developed:

(i) Insulation and sealing on the glass melting furnace.
(ii) Modification of the furnace structure.
(iii) Enhancement of heat recovery with improved regenerators.
(iv) New types of oil burner and better combustion efficiency.
(v) Higher efficiency of coal gas generation, including better automatic controls.
(vi) Improved feeders for charging raw materials.
(vii) Instrumentation for process and combustion control.
(viii) Higher efficiency fans.

3.104 Overall, these types of improvement can give energy savings of 30-40 percent for existing furnaces.

Ceramics

3.105 Energy consumption in this part of the sector is rather high and therefore a good potential for improvement clearly exists. Some typical measures already being adopted include:

(a) **Fuel Changes.** Because coal and heavy oil are used extensively, indirect firing methods have been used to avoid pollutants affecting product quality. To improve heat transfer and to save energy, clean gas—such as purified coal gas and city gas—may sometimes be utilized.

(b) Adoption of modern kiln technologies—such as the replacement of old downward draft and multi-pass kilns by roller hearth and shuttle kilns.

(c) Modifications for energy saving on existing kilns—consisting of a number of items which apply in many cases, such as new oil and gas burners, low mass kiln cars and accessories, better insulating materials for kilns, and heat recovery from exhaust gases to dry and preheat incoming materials.

Clay Bricks and Tiles

3.106 Measures being taken to improve energy efficiency in the brick and tile industry range from increasing the utilization of carbon-containing wastes such as fly ashes and coal washery rejects—as already mentioned above—to the increased use of hollow bricks. In China, the proportion of hollow bricks remains about 0.3 percent of the national output, while other countries use hollow bricks extensively. Hollow bricks require less clay per unit volume, consume less fuel for firing in the kiln, are lighter and easier to handle during construction, and have superior insulating properties when used in typical buildings. A void space of say 30 percent is quite feasible without substantially altering the properties of the brick but saving about 20 to 25 percent of the energy needed in manufacturing. By ensuring proper quality control in manufacturing, large energy savings are thus possible in the clay brick industry.

3.107 In the building material industry in general, there are possibilities for using waste materials such as slags and fly ash to make lightweight bricks and panels for buildings. These can save large amounts of energy currently used to make clay bricks. The use of aerated concrete could also be encouraged.

3.108 With respect to the kilns and manufacturing process itself, better insulation to reduce heat losses and increased use of waste heat for artificial drying is being adopted in many plants. The internal structure of existing kilns should be checked to ensure that there is no bypassing of useful heat direct to the stack due to internal gas duct faults. Also, the continued use of small kilns with old and primitive technology must be questioned and the lowest efficiency plants should be shut down.

Lime

3.109 The main thrust of efficiency improvements is to replace old backward kilns by mechanized kilns using modern technology. Other modifications being adopted include improved insulation and enhanced CO_2 recovery for alternative uses. Management of operations needs upgrading too, with better day to day control of the size of limestone fed to the kiln, of the coal to limestone ratio, of the combustion air volume and the use of waste heat. Some economies in fuel costs are also achievable by utilizing coal washery wastes. It is estimated that energy savings of about 20 percent in terms of TCE/t product are possible using such simple and well known measures.

Projected Industry Outputs and Energy Consumption

3.110 There is a great demand for building materials of all types and the sector is expected to continue to show strong growth, generally faster than the average growth of the economy. Estimated outputs of key products are thus as follows:

		1990	2000	2010
Cement	10^6 tons	210	460	500
Flat glass	10^6 cases	81	150	180
Floor and wall tiles	million m^2	227	300	350
Sanitary ware	10^6 tons	0.17	0.25	0.32
Bricks, tiles	10^9 pieces	497	650	700
Lime	million t	94	180	220

3.111 While most products will increase in output, brick production is expected to slow down and decline as lighter and more efficient products replace conventional clay bricks.

3.112 In terms of energy use, the importance of the building material sector will also remain high. Assuming efforts are continued to improve energy efficiency, the forecasted energy consumption for the sector is as follows:

(10^6 TCE)	1990	2000	2010
Cement	40.7	62.5	87.9
Flat glass	3.1	4.7	5.0
Bricks and tiles	54.4	70.0	70.0
Lime	10.5	18.0	21.0
All others	14.2	24.8	26.1
Total	122.9	180.0	210.0

Generic Investment Options

3.113 The main opportunities for energy saving and reduction of greenhouse gas emissions are in the cement industry. Three typical items were chosen for detailed analysis as case studies:

(a) **B1** Renovation of old cement plants by upgrading dry process kilns to preheater/precalciner systems.

Much of the Chinese cement industry was established before 1950 and utilises obsolete equipment and outdated processes. With few exceptions even those plants using the dry process route have problems with old equipment, often operated long after the end of its economic life. This causes poor energy efficiencies and high levels of pollution, especially dust emissions. Profitabilities are often low. The renovation of typical dry process plants can therefore make a major contribution to the well-being of the industry, by replacing old dry kilns with modern preheater and precalciner kilns.

(b) **B2** Conversion from wet process to dry process kilns.

More than half the kilns used in large and medium-scale enterprises are using the traditional wet process in which raw materials are mixed with water during the initial grinding stages and enter the kiln as a slurry. This water requires extra energy to evaporate during the clinkering step. Most modern plants use the dry process route in which the raw materials are processed without water addition, consuming much less energy per ton of cement produced. Conversion of wet process plants to the dry process offers the opportunity to save significant energy and to upgrade equipment generally.

(c) **B3** Renovation of small-scale vertical cement kilns.

Out of a total cement production of about 250 million tons per year, 190 million tons are made in small-scale vertical kilns in over 5,000 plants. While many of the oldest and smallest plants with outdated equipment in poor condition will undoubtedly be shut down in the next few years, many plants will remain in operation to satisfy the growing market demand for cement. A large number of measures can be taken to upgrade the plants, including improvements to raw material preparation and mixing stages, adoption of modern instrumentation for better process control, and modernization of exhaust gas dust removal equipment.

3.114 Actual plant data were collected at representative cement plants for each option. Internal rates of return and paybacks, including construction time, were calculated as follows:

	IRR %	Payback, years
B1 Renovation of dry kilns	16.9	11
B2 Wet to dry conversion	19.2	10
B3 Vertical kiln renovation	32.3	7

3.115 Based on the characteristics of the cement industry, the following forecasts were made for the business as usual and accelerated scenarios:

		1990	2000	2010
B1 Renovation of dry kilns (million tpy cement):				
BAU	Old kilns	6.0	3.0	0.0
	Renov. kilns	0.0	3.0	6.0
Accel.	Old kilns	6.0	0.0	0.0
	Renov. kilns	0.0	6.0	6.0
B2	Wet to dry conversion (million tpy cement):			
BAU	Wet process	22.0	22.0	11.0
	Dry process	0.0	0.0	11.0
Accel.	Wet process	22.0	22.0	0.0
	Dry process	0.0	0.0	22.0
B3	Vertical kiln renovation (million tpy cement):			
BAU	Old kilns	50.0	37.5	0.0
	New kilns	0.0	12.5	50.0
Accel.	Old kilns	50.0	32.5	0.0
	New kilns	0.0	17.5	50.0

3.116 Further details of the assumptions made and the energy and emissions factors used in the calculations are given in Annex A.

Projected Impacts on Energy and Emissions

3.117 Using the forecasts given above, the expected impacts on energy use in the building materials sector were calculated as follows:

	Savings 10^3 TCE/yr by 2000		Savings 10^3 TCE/yr by 2010	
	BAU	Accel.	BAU	Accel.
B1 Renovation of dry kiln	376	752	752	752
B2 Wet to dry conversion	0	0	865	1,730
B3 Vertical kiln renovation	776	1,086	3,103	3,103

3.118 Reductions in CO_2 emissions were estimated as follows:

	CO_2 reduction 10^3 tpy by 2000		CO_2 reduction 10^3 tpy by 2010	
	BAU	Accel.	BAU	Accel.
B1 Renov. of dry kilns	245	489	489	489
B2 Wet to dry conversion	0	0	560	1,120
B3 Vertical kiln renov.	380	531	1,518	1,518

Emissions

3.119 Major pollutants from the building material industries include dust, CO_2, nitrogen oxides and SO_2 from the manufacture of cement. Cement dust is often a highly visible pollution problem, and greater attention needs to be paid to removal of particulates from stack exhausts using bag filters or electrostatic precipitators. The recovered dust can often be recycled to be mixed with the cement product. There are regulations to limit dust emissions but enforcement is sometimes lacking.

3.120 Carbon dioxide is produced as a part of the cement making process itself. A major component of the raw material is calcium carbonate which is heated in the kiln and CO_2 is driven off in the reaction. The amount of CO_2 released is about 1-1.1 tons per ton of clinker produced. Thus, in 1991, the production of clinker was 176.8 million tons, corresponding to a release of say 180 million tons of CO_2.

3.121 The emission of nitrogen oxides varies according to combustion conditions. The following estimates have been made of NO_X emissions for different types of kiln:

Type of kiln	NO_X ppm	
	Average	Maximum
Precalciner	410	1,010
Preheater	500	1,260
Lepol (semi-wet)	270	900
Kiln generating elec. with waste heat	460	680
Wet process	550	1,120
Vertical shaft	200	n.a.

At present, there are no limitations on NO_X emissions in China. In Japan, for example, there are limits of 480 ppm for old and 250 ppm for new kilns.

3.122 The emission of SO_2 from cement plants is not a major problem as the coal used is typically under 2 percent sulphur. In any case, much of the SO_2 is absorbed by the cement process materials.

3.123 Carbon monoxide release from conventional rotary kilns is normally not a problem as combustion is completed within the kiln. For vertical shaft kilns, however, there are sometimes problems due to incomplete combustion, resulting in some cases from inadequate supply of combustion air or poor distribution of the air in the shaft. CO can reach 2-3 percent in the exhaust gases, posing a safety and health hazard.

3.124 Pollutants from the glass industry consist of particulates from the raw materials and some gaseous emissions generated by the process reactions. Many of the raw materials contain carbonates and sulphates, which lead to emissions of CO_2 and SO_2 respectively. NO_X is generated in the combustion process in the melting furnace. As a guide, the emissions from a typical glass plant amount to 12.2 nm^3 of waste gas per 100 gm of raw material batch, of which CO_2 is 7.9 nm^3 (15.5 kg) and SO_2 0.5 nm^3 (1.42 kg). In addition, there are the emissions from the fuel to consider. As a guide, 1 nm^3 of coal gas (heating value 1430 kcal/nm^3) produces 2.05 nm^3 exhaust gas of which 0.35 nm^3 is CO_2. For heavy fuel oil burning (heating value 10,000 kcal/kg), the exhaust gas is about 13.5 nm^3/kg fuel of which CO_2 is 1.7 nm^3.

3.125 Pollutants from the ceramics, clay brick and tile industries are all produced during fuel combustion; there are no significant effects from chemical reactions. In the case of the lime industry however, a large amount of CO_2 is released as calcium carbonate decomposes. The quantity is about 1.18 tons of CO_2 per ton of lime produced, including the CO_2 from the fuel.

3.126 For 1991, the total emission of CO_2 is thus estimated to have been 450 million tons, with contributions as indicated below. With respect to emission levels in the future, projected industry outputs and energy consumptions have been used to give the following forecasts for emissions of CO_2:

	1991	2000	2010
	(million tons)		
Cement	177	260	329
Flat glass	7	9	12
Ceramics	7	10	13
Bricks and tiles	114	152	145
Lime	125	165	188
Others	20	24	28
Total	450	600	715

D. Paper

Industry Profile

3.127 The Chinese paper industry has grown steadily since 1949 at an average of 12.5 percent per year until it now produces over 17 million tons per year (1992), ranking fourth in the world. Production statistics for 1990 are as follows:

Pulp	10^6 t	12.303
Paper and board	10^6 t	13.719
Number of grades		500
Products:		
Printing, writing paper	%	27
Wrapping, packaging	%	28
Household, sanitary	%	5
Board	%	40

Further increases in paper and board production were seen in 1991 and 1992, to 14.28 and 17.25 million tons respectively. About 60 percent of the raw material is straw.

3.128 Most of the production is consumed domestically. Production of fine coated printing papers, cigarette paper, and various liner boards cannot meet demand and therefore some products are imported. In 1990, for example, imports were 342,000 tons of pulp and 962,000 tons of paper and board: about 385,000 tons of paper and board products were exported.

3.129 Although the output of paper products is large on a world scale, per capita consumption is relatively low. The total world average figure was 44.8 kg per capita in 1990; for the USA it was 311.4, in Asia 19.8, and in China it was only 12.6 kg.

3.130 The industry in China comprises 5,360 paper-making enterprises with 1.25 million employees. While the average production of all paper mills is around 2,550 tons per year, the range of plant sizes is great. For example, 242 large and medium-size enterprises produced 5.067 million tons in 1990, 37 percent of the total national production: each of these plants produces over 10,000 tons annually. The industry is spread widely in China, with Shandong, Henan and Guangdong Provinces producing the largest tonnages. Of these, only Henan Province represents over 10 percent of the national output of pulp or paper (Table 3.29).

3.131 Production responsibilities in the industry are divided into several branches—such as plants under agencies for light Industry, forestry, agriculture, military, etc. Under the Ministry of Light Industry heading, there are 1,716 plants producing 56 percent of the national total.

Energy Use

3.132 Of the total energy used in pulp and paper mills, electricity accounts for 30 percent and heat energy 70 percent. Electricity is used mainly in stock preparation and pulping for sawing and chipping wood, cutting straw, grinding and screening, as well as for operating motors on pumps and blowers. Fuels are used mainly for the production of steam, which in turn is used for electricity generation in some plants and process use in all plants, such as cooking, bleaching, black liquor evaporation and the drying of pulp and paper.

3.133 Table 3.30 shows the consumption of different energy forms. The industry consumed 12.25 million TCE of fuels and 11.98 billion kWh of electricity in 1990, a total of 16.94 million TCE. The installed power of electrical equipment in 1990 was estimated at 4,500 MW. The total energy consumed for paper-making was 2.5 percent of the national energy consumption: this is relatively low, the corresponding figure being about 10.5 percent in the USA and 5 percent in Japan.

3.134 The cost of energy for the paper industry is 10-15 percent of total manufacturing costs. This can of course vary widely for different enterprises in different regions and is generally based on the market price for energy. The paper industry purchases relatively little energy at "planned" state-controlled price levels. Typical figures for April 1992 were:

	"Planned" prices	Market prices
Fuel oil (Y/ton)	290	480
Raw coal (Y/ton)	65	100-160
Electricity (Y/kWh)	0.16	0.25-0.60

3.135 With respect to electricity generation within the paper industry, only 60 mills have their own power stations out of over 5,000 enterprises in China. Typical boiler efficiencies are 80 to 90 percent. Some statistics for the equipment in use in 1990 is as follows:

	Number	Capacity
Boilers	152	5,300 t/h
Steam Turbines:		
Back pressure, extraction (non condensing)	61	163 MW (40.0%)
Extraction & condensing)	29	109 MW (46.4%)
Condensing only	5	55 MW (13.6%)
Total turbines	95	407 MW

3.136 The trend is toward the shutting down of ordinary condensing turbines and their replacement by extraction types. The size range of turbines is wide, although about 40 percent can be considered large:

Size, MW	Installed, MW	Percent
< 3	42.7	10.5
3 - 6	69.6	17.1
6 -12	139.6	34.3
> 12	155.1	38.1
Total	407.0	100.0

Table 3.29: PRODUCTION DISTRIBUTION FOR THE PAPER INDUSTRY, 1990

Province, municipality or region	Pulp		Paper and board	
	10^3 t	percent	10^3 t	percent
Beijing	132.0	1.07	254.1	1.85
Tianjin	166.3	1.35	267.5	1.95
Hebei	853.3	6.94	887.5	6.47
Shanxi	363.0	2.94	354.4	2.58
Neimenggu	135.1	1.10	135.9	0.99
Liaoning	774.9	6.30	775.0	5.65
Jilin	511.7	4.16	570.2	4.16
Heilongjiang	460.6	3.74	535.3	3.90
Shanghai	343.9	2.80	464.9	3.39
Jiangsu	663.2	5.39	748.1	5.45
Zhejiang	332.2	2.70	785.2	5.72
Anhui	267.4	2.17	383.6	2.80
Fujian	538.1	4.37	520.9	3.80
Jiangxi	249.8	2.03	255.9	1.87
Shandong	964.0	7.84	1161.1	8.46
Henan	1476.7	12.00	1484.1	10.82
Hubei	349.8	2.84	430.3	3.14
Guangdong	966.1	7.85	1041.3	7.59
Guangxi	336.5	2.74	335.0	2.44
Hainan	3.6	0.03	4.0	0.03
Sichuan	816.1	6.63	774.4	5.64
Guizhou	66.0	0.54	62.1	0.45
Yunnan	163.6	1.33	154.3	1.12
Shaanxi	447.7	3.64	417.5	3.04
Gansu	105.2	0.86	102.4	0.75
Qinghai	4.0	0.03	7.1	0.05
Ningxia	70.4	0.57	66.8	0.49
Xinjiang	97.6	0.79	90.9	0.66
Subtotal	11,657.8	94.76	13,069.8	95.30
All others	302.7	2.46	71.9	0.52
Net imports	342.0	2.78	577.0	4.21
Total	12,302.5	100.00	13,718.7	100.00

3.137 Units with a capacity of 6 MW or higher are normally found in larger enterprises built during the Sixth Five-Year Plan. Those under 3 MW were typically installed during the Seventh Five-Year Plan and many are associated with cogeneration systems.

Table 3.30: Energy Consumption Data for the Pulp and Paper Sector, 1990

Subsector	Output of paper products 10^3 T	Energy Consumed: Fuels 10^6 TCE							Electricity		Total energy	
		Steam coal	Coking coal	Coke	Oil	Nat. Gas	Other	Total Fuel	10^9 kWh	10^6 TCE	10^6 TCE	Percent
Light industry plants	7,710.0	7.675	0.000	0.000	0.403	0.027	0.000	8.105	7.92	3.105	11.210	66.16
Small scale												
farms	380.0	0.395	0.000	0.000	0.021	0.000	0.000	0.416	0.41	0.161	0.577	3.40
townships	5,230.0	3.125	0.000	0.000	0.164	0.000	0.000	3.289	3.22	1.262	4.551	26.86
Small/forestry	100.0	0.104	0.000	0.000	0.005	0.000	0.000	0.109	0.11	0.043	0.152	0.90
All other	300.0	0.313	0.000	0.000	0.016	0.000	0.000	0.329	0.32	0.125	0.454	2.68
Totals	13,720.0	11.612	0.000	0.000	0.609	0.027	0.000	12.248	11.980	4.696	16.944	100.00
percentages		68.53	0.00	0.00	3.59	0.16	0.00	72.28	–	27.72	100.00	

Specific Energy Consumption

3.138 The specific energy consumption differs greatly from enterprise to enterprise, depending on the scale of operation, the materials used for fibre, the specific processes employed, product grades and quality, and management. Most pulp producers in China are integrated, with few producing only pulp for the market. Many paper mills —especially smaller ones in cities—purchase pulp or use waste paper. Township paper-making enterprises mainly produce lime straw pulp to make straw board or use waste paper to make packaging materials. Paper mills under forestry agencies mainly produce wood-based unbleached pulp and board. Enterprises under the Ministry of Agriculture and within the military system are straw based integrated paper mills. For the same grade of paper or board, the unit energy consumption of plants under the Ministry of Light Industry is generally lower than plants under other agencies.

3.139 The average unit consumption was 1.23 TCE per ton of product:

	Output 10^3 t	Energy inc. electricity 10^3 TCE	Unit energy consumption TCE/t
Light industry	7,710	11,200	1.45
Agriculture:			
Farm	380	576	1.52
Township	5,230	4,557	0.87
Forestry	100	152	1.52
Army and other	300	457	1.51
All China	13,720	16,942	1.23

The energy consumption for the paper industry in 1990 represents about 4.6 TCE per Y 10,000 output value.

3.140 Typical energy consumptions for certain activities in plants under the Ministry of Light Industry are as follows:

Product	Units	1985	1988	1989	1990
Heat Energy:					
Pulp	TCE/t pulp	0.64	0.62	0.68	
Paper, board	TCE/t product	0.99	0.92	0.87	
Electricity:					
Mechanical					
Wood pulp	kWh/t	1,522	1,588	1,560	1,566
Newsprint	kWh/t	556	565	568	583

These figures show fluctuations over time, although the general trend seems to be down for thermal energy and up for electricity.

3.141 In integrated pulp and paper mills, the average energy consumption was 1.55 TCE per ton of paper, based on 1990 data for 870 enterprises. The cost of energy for these plants represents 10 to 15 percent of the total production cost. These larger plants normally use medium pressure boilers with efficiencies in the region of 80 percent, while smaller plants have only low pressure boilers with efficiencies as low as 50-60 percent. The total steam raising capacity in the paper industry is around 14,000 t/h.

3.142 The efficiency of electricity generation varies considerably. For 42 plants investigated, the following data were obtained:

Energy consumption, kg CE/kWh	No. of plants
< 0.404	15
0.404-0.600	12
> 0.600	15
Min 0.155/ avg 0.40/ max 0.70	42

Of the figures given for energy consumption, about 15-25 percent of this is for internal power plant use.

Energy Efficiency Trends

3.143 With respect to changes in energy efficiency, the industry has paid increasing attention to all aspects of operations. In addition to strengthening enterprise management and training personnel, the following measures have been adopted:

(a) **Increased Application of Cogeneration.** Installed capacity MW in 1990, with self-generated electricity, totalling 1.65 billion kWh. However, only 60 mills out of about 5,000 have their own cogeneration equipment, although essentially all newly built medium and large enterprises now include cogeneration systems.

(b) **Increased Black Liquor Recovery.** Energy recovery from black liquor is now equivalent to about 200,000 TCE annually.

(c) **Recovery of Waste Heat.** Including heat from paper machine hoods.

(d) **Use of Wood Wastes.** These include bark, sawdust, wood chips and straw dust, which are now being used in waste boilers.

(e) **Increased Instrumentation.** This includes computer control of operations such as rapid cooking of straw at low temperatures, and on-line paper moisture measurement.

(f) **Various Process Improvements.** These include recycling white water, reducing the moisture content of formed paper entering the drying section, condensate recycle from cylinder dryers, and greater use of continuous digesters.

3.144 The results of such activities are suggested by the following figures for plants under the Ministry of Light Industry:

	1985	1990	Growth %/y /a
Output value:			
Y 10^9 (1990)	16.69	24.56	8.03
Enterprises	1,616	1,716	
Production (million tons)	6.59	7.71	
Energy consumption (10^6 TCE)	10.01	11.20	2.27
Energy/output			
TCE/Y 10,000	6.00	4.60	
TCE/t	1.52	1.45	

/a Energy growth %/Output growth % = 0.28.

3.145 The data suggest the savings are about 5.3 percent per year over the 5 years. However, although useful savings have been achieved, some of the improvement is due to changes in the product structure in the industry. For example, letter press paper has been upgraded to offset paper quality by many enterprises, and ordinary newsprint to high grade offset newsprint. Higher value-added products such as kraft liner board and white board are making up a greater proportion of output. These changes lead to a higher output value with relatively modest energy increases. In addition, there have been increases in the use of imported pulp and recycled paper, thus decreasing the energy needs for pulp-making.

Potential for Improvement

3.146 Apart from potential management deficiencies, there are five major reasons for high energy consumption by the Chinese paper industry:

(a) **Structure of Energy Consumption.** In China, coal represents about 95 percent of fuel use while the paper industry in many western countries uses a high proportion of natural gas.

(b) **Raw Materials.** In 1990, wood fiber made up only 14.6 percent of raw material in China, while in other countries it is generally 90 percent or more. Straw is the main source of fibers for paper production and there is therefore very little wood waste or bark that can be used as a fuel. On the contrary, there are large quantities of straw and reed dust that are not utilized. It is believed there are only very few waste dust boilers in China.

(c) **Black Liquor Recovery.** Although this is increasing, recovery remains low. In 1990, there were 57 black liquor recovery systems in service with a capacity of 0.45 million tons alkali recovery per year: the actual amount recovered amounted to 0.35 million tons. The efficiency of recovery is about 80-90 percent in China compared with typical levels of 90-95 percent overseas. Of the 57 mills with black liquor recovery, only 8 have cogeneration systems, the remainder simply make low pressure steam for heating. The concentration of solids in black liquor from straw pulping is lower than for wood pulp processing, thus the energy requirement for alkali recovery is higher.

(d) **Enterprise Scale.** The average production of Chinese paper enterprises is 2,550 tpy, and only 37 percent of annual production is made by plants with capacities in excess of 10,000 tpy. Out of over 5,000 plants, only about 200 may be classified as medium or large. Overseas, plant sizes are usually much greater: typically, paper and board production of enterprises is 60,000 tpy. The economic application of black liquor recovery and cogeneration systems is therefore less often found in China.

(e) **Equipment Technology.** This tends to be somewhat backward in China and equipment at most medium and large enterprises can be considered equivalent to international standards of the 1960s and 1970s. Paper machines in China are usually under 2 meters in width and run at speeds of 200 m/min or less, while corresponding machines in western plants are often 5-10 meters in width and run at 800-1200 m/min.

3.147 Some potential changes which should lead to lower energy use include higher levels of black liquor recovery and cogeneration, as already indicated. In addition, improvements in digester technologies are being widely adopted, such as continuous systems which replace both spherical and vertical batch digesters. Increased water recycling is also being encouraged, including more condensate recovery from paper machine drying cylinders (currently estimated at only 50 percent). Greater use of wastes such as bark, wood chips and straw dust is also expected. The increased use of waste paper as a raw material could also lower overall energy consumption. Currently, only 27 percent of paper raw material is made up from waste paper and it is thought that this could be increased to about 30-35 percent in the short to medium term.

3.148 Other technical measures include improvements that are not exclusive to the paper industry, such as improved boiler operations, the use of variable speed electric motor drives, elimination of condensing turbines in electricity production, replacing low efficiency blowers and pumps, improving steam system insulation, installing more steam traps, and replacing defective traps more frequently.

3.149 Longer-term technological developments are expected to concentrate on long fiber pulps and the adoption of more wood-based pulping. Larger plant sizes can be expected, with new wood pulp mills in the range of 50,000 tpy capacity or more, and nonwood pulp mills to 17,000 tpy or above.

3.150 With respect to environmental protection, reduction in waste water discharges and increased water recycling will be pursued. Higher levels of black liquor processing and alkali recovery will help, as will higher levels of waste water treatment. Lower energy consumption in general will lead to lower emissions to atmosphere of CO_2, SO_2 and particulates.

Projected Industry Outputs and Energy Consumption

3.151 It is expected that the annual growth rate of the paper industry will be a little higher than the overall growth rate of the economy. It is also anticipated that the quality of most major products will continue to improve to world standards. The following figures for output and corresponding energy use and emissions have been estimated, assuming the achievement of higher energy efficiency and greater attention to pollutant emissions:

Generic Investment Options

3.152 Based on a review of the paper industry and likely changes in technologies used, two case studies were developed for the paper industry:

		1990	1995	2000	2010
Output	10^6 tons	13.72	20.15	25.00	35.00
Energy					
Fuels	10^6 TCE	12.25	16.73	22.04	22.75
Electricity	10^9 kWh	11.98	16.70	22.27	23.10
	10^6 TCE eq	4.79	6.68	8.91	9.24
Total	10^6 TCE	17.04	23.41	0.95	31.99
Specific e.c.	TCE/ton	1.24	1.16	1.07	0.91
Emissions:					
CO_2	10^3 tons	2,340	3,194	4,210	4,345
SO_2	10^3 tons	296	360	445	428
SO_2 removal	%	10	20	25	30

(a) L1 Black Liquor Recovery

In pulp plants, raw materials are treated with caustic soda as an essential first step. Much of the spent caustic is discharged by Chinese plants to local rivers and is responsible for 80 percent of the organic pollutant load in paper industry effluents. Processing of black liquor is well established in most developed countries and is used to reduce pollution emissions, to recover caustic soda for reuse in the pulping process, and to recover energy by burning combustible materials in the black liquor itself.

(b) L2 Cogeneration

The paper industry is a large consumer of both electricity and steam. Most paper mills in China generate their own steam in boilers which operate at low pressures and moderate efficiencies. Some of the larger enterprises generate their own electricity, also using boilers to produce steam at relatively low pressure and at efficiencies of 50-60 percent. Increased adoption of cogeneration systems in the paper industry will permit much higher generation efficiencies for both steam and electricity, partly through the application of a process that is inherently more efficient than separate generation and partly by the effect of replacing old and outdated equipment.

3.153 As indicated previously, these technologies have already been adopted by some paper plants and therefore it is useful—based on actual plant experiences—to determine their economic viabilities, to assess impacts on industry energy consumption and greenhouse gas emissions from their further adoption, and to estimate the potential energy and pollution benefits from accelerating the present rate of adoption of the technologies.

3.154 The details of the two case studies are reported elsewhere. Analyses gave the following internal rates of return and paybacks (including construction times):

	IRR %	Payback, years
L1 Black liquor recovery	24.6	5
L2 Cogeneration	24.5	9

3.155 Based on the characteristics of the sector, the following forecasts of adoption of these technologies were made:

		1990	2000	2010
L1 Black liquor recovery (10^6 tpy pulping capacity):				
BAU	Without BL recovery	1.2	0.8	0.0
	With BL recovery	0.0	0.4	1.2
Accel.	Without BL recovery	1.2	0.6	0.0
	with BL recovery	0.0	0.6	1.2
L2 Cogeneration (10^6 tpy paper products):				
BAU	Plants without cogeneration	2.4	1.9	0.0
	Plants with cogeneration	0.0	0.5	2.4
Accel.	Plants without cogeneration	2.4	1.4	0.0
	Plants with cogeneration	0.0	1.0	2.4

Details of the assumptions made including energy and emissions factors are given in Appendix A.

Projected Impacts on Energy and Emissions

3.156 Based on the above forecasts, the expected impacts on the energy consumption of the paper sector are as follows:

	Savings 10^3 TCE/yr by 2000		Savings 10^3 TCE/yr by 2010	
	BAU	Accel.	BAU	Accel.
L1 Black l. recovery	74	110	221	221
L2 Cogeneration	17	33	79	79

Reductions in CO_2 emissions were forecast as follows:

	CO2 reduction 10^3 tpy by 2000		CO2 reduction 10^3 tpy by 2010	
	BAU	Accel.	BAU	Accel.
L1 Black l. recovery	253	379	759	759
L2 Cogeneration	11	21	50	50

Emissions

3.157 The paper industry releases air pollutants through the combustion of fuels in boilers, in common with most manufacturing operations, but the major pollution impact of the industry is on water pollution. Spent chemicals such as caustic soda containing organic contaminants are discharged to local rivers and lakes. Increasing the recovery of caustic soda from black liquor will thus contribute significantly to reducing local water pollution.

3.158 Estimates of the current air pollutant emissions and forecasts through to 2010 are as follows:

		1990	1995	2000	2010
Industry output	10^6 tons	13.72	20.15	29.00	35.00
Emissions:					
CO_2	10^3 tons	2,340	3,194	4,210	4,345
SO_2	10^3 tons	296	360	445	428
SO_2 removal	%	10	20	25	30

3.159 The most important measures to reduce air pollutant emissions are to improve combustion efficiency on existing boilers and to ensure that new boiler designs adopt good modem practice. Other pollutants are released from associated operations such as lime kilns and digesters: good management is needed to keep operating practices at the highest levels, and to ensure that proper environmental protection equipment is fitted (e.g., dust collectors on lime kilns and boilers).

E. TEXTILES

Industry Profile and Products

3.160 The textile industry may be divided into "upstream", "midstream" and "downstream", according to the process route from fibers to final products:

(a) **Upstream** Covering raw fibre production, both natural and synthetic. Natural fibers include cotton, silk and wool, while synthetic fibers cover a wide range of materials such as viscose, acetate, polyester, nylon and acrylic materials. Preparation of natural fibers is classified as an agricultural activity and that of chemical fibers as industrial.

(b) **Midstream.** Processing of fibers into fabrics. This may be further divided into the manufacture of cotton, wool, silk and artificial fibers, including spinning, weaving, knitting, bleaching, dyeing, printing and finishing. These are the main activities of the textile industry.

(c) **Downstream.** Preparation of final products from fabrics. This covers the making of garments, footwear and headwear, and the manufacture of curtains, carpets and industrial textiles.

3.161 The textile industry in China is amongst the largest in the world, with the number of cotton yarn spinning spindles ranked first, of wool spinning spindles second and chemical fibre output fourth. About 0.4 million tons of yarns and silks and 6 billion meters of fabrics are exported annually.

3.162 In 1990, there were 11,223 enterprises reporting to the Ministry of Textile Industry with an output value of Y 198 billion. The total employed was 7.46 million. These figures do not include establishments operated by TVEs which are very numerous but are often quite small plants. Plants under the Ministry can be divided as follows:

	Number	Percent
Large	472	4.2
Medium	1,251	11.1
Small	9,500	84.7
	11,223	100.0

3.163 For the record, the classification is made as follows:

	Large	Medium	Small
Cotton manufact.	>100,000	50-100,000	< 50,000 spindles
Dyeing, printing	> 100	50-100	< 50 million M/y
Chemical fiber	>8,000	3-8,000	< 6,000 tpy staples

3.164 In terms of numbers, the large and medium plants represent about 15 percent of the sector and provide about two thirds of the output value of the textiles industry.

3.165 Enterprises are located all over China, although one third are in the east:

	Number	Percent
North	1,442	12.9
Northeast	1,458	13.0
East	3,804	33.9
Middle, south	2,724	24.3
Southwest	1,094	9.7
Northwest	701	6.2
	11,223	100.0

3.166 Production statistics for the textile industry, excluding TVE plants, are as follows for 1985-90:

		1985	1986	1987	1988	1989	1990
Number of enterprises		14,476	14,600	14,701	14,585	10,913	11,223
Employees (year end)	10^6	6.69	7.00	7.36	7.68	7.35	7.46
Production data							
Chemical fiber	10^3 t	948	1,017	1,175	1,301	1,478	1,650
Cotton yarn	10^6 t	3.53	3.98	4.37	4.66	4.77	4.62
Cotton fabric	10^9 m/a	14.67	16.47	17.31	18.79	18.92	18.80
Printed/dyed fabric	10^9 m/a	7.53	7.95	8.31	9.52	8.70	9.10
Woolen fabric	10^6 m/a	218.16	251.86	265.40	286.11	279.60	295.00
Silk	10^3 t	42.20	47.20	51.90	51.00	52.20	56.50
Garments	10^9 pieces						3.0
Footwear	10^6 pairs						765
Headwear	10^9 pieces						117

/a Standard width of fabric is 1 meter.

3.167 The following data are available on capacities in 1990:

	Capacity
Chemical fibers	2.02 10^6 tpy
Cotton yarn spinning	38.82 10^3 spindles
Cotton fabric weaving and knitting	0.86 10^6 looms
Wool yard spinning	2.65 10^6 spindles
Wool fabric weaving and knitting	0.33 10^6 looms
Silk reels	2.4 10^6 ends
Silk textile weaving and knitting	0.18 10^6 looms
Cotton fabric printing and dyeing	13.2 10^9 meters/y

3.168 The range of products produced in the Chinese textile industry is considered limited compared with developed countries. There are also problems of variability in quality and low added value. Textile exports from China achieve a value of about $ 5000 per ton while exports from developed countries are valued at twice that amount. For the world industry on average, the consumption of chemical fibers for textile production amounts to 46 percent while China uses only 20 percent.

3.169 The structure of textile products lags behind many developed countries, as the following table of relative production values:

(percent)	Fabrics for garments	Curtains, wall coverings carpets, and automotive use	Industrial uses—belts, tires, filters, etc.
USA	40	37	23
W. Europe	50	34	16
Japan	35	30	35
China	75	15	10

3.170 The textile industry also suffers from old and outdated equipment, with about one third of the cotton manufacturing machinery having a life of 30 years or more. Much Chinese machinery is still at an early stage of development with respect to electronic control. It is believed that about half the textile machinery built today in China is only at the international level of the 1960s. For example, open end spinning machines, shuttleless looms and rotary screen printing machines represent 3, 3 and 10 percent of the market in China compared with 13, 15 and 50 percent in the world market.

3.171 Labor productivity is also low in China. For example, 30 man-hours are needed to produce one ton of yarn, 3.5 times as much as Japan today and about the same as Japan in the mid-1960s.

3.172 The textile industry is however modernizing as it expands to meet growing domestic and international demands. Production is expected to increase by 0.45 million tpy by 1995 compared with 1990 and by a further 1 million tpy by 2000. The proportion of garments, knitted goods, decorative and industrial textiles will increase. Quality is expected to increase, as will the diversity of products, to meet market requirements.

Energy Use

3.173 In 1990, the resources consumed by the textile industry were as follows:

	Consumption	TCE	Percent
Coal	15.21 10^6 t	15.59	56.4
Fuel oil	0.48 10^6 t	0.69	2.5
Electricity /a	23.3 10^9 kWh	9.65	34.9
Purchased steam	47,940 10^9 kJ	1.66	6.0
Coal gas	102 10^9 M3	0.06	0.2
		27.65	100.0

/a Under 3 percent self generated, which is included in the figure quoted for kWh (fuels for self generation are included in the coal, oil, etc.).

3.174 The energy consumption may be allocated to various parts of the industry as follows:

		Upstream chem. fibers	Midstream textiles	Downstream garments etc.	Misc. uses	Total
Coal	10^6 t	2.63	11.56	0.31	0.71	15.21
Fuel oil	10^6 t	0.09	0.36	0.01	0.02	0.48
Electricity	10^9 kWh	4.1	18.2	0.27	0.73	23.3
Purch. steam	10^9 kJ	8,450	38,450	100	850	47,940
Coal gas	10^6 m^3	-	110	-	10	120

3.175 A complete breakdown of energy consumption by the Chinese textile industry is given in Table 3.31.

3.176 With regard to energy prices, typical regional prices for electricity are:

North China	0.25 to 0.30 Y/kWh
East China	0.40 to 0.50
South China	0.60 to 0.80

3.177 As a percentage of total manufacturing cost, including raw materials, the cost of energy is about 3.5 to 5 percent for textile production, 4.5 to 6.5 percent for chemical fibre production and 5 to 6 percent for dyeing and printing.

Specific Energy Consumption

3.178 In 1990, unit energy consumptions were as follows:

	Electricity kWh/t	Fuels TCE/t
Synthetics		
Viscose staple fibers	1,999	2.28
Viscose filament yarns	10,439	9.17
Nylon fibers	3,564	1.47
Polyester staples	749	0.72
Acrylic fibers	1,540	4.99
Vinylon	2,291	2.34
Natural		
Cotton yarns	2,129	n.a.
Cotton fabrics	25	n.a.
Dyed and printed fabrics	n.a.	43 kgCE/100 m
Natural silk	n.a.	1,680
Silk fabrics	51 kWh/100 m	n.a.

Energy Efficiency Trends

3.179 Based on constant 1980 yuan, the ratio of coal use to output value dropped about 16 percent from 1980 to 1990:

	Output value 10^9 RMB	Energy use 10^6 TCE	Ratio TCE/10,000 RMB
1980	66.6	16.31	2.45
1990	136.2	27.65	2.03

3.180 It is estimated that the annual energy savings amount to 3.4 percent. This has been achieved by improving management and by investments in new equipment and technologies. For example, textile enterprises have made strong efforts to introduce good energy management practices throughout the industry, including better metering and reporting, better data analysis, improved scheduling of operations, training programs on

Table 3.31: Energy Consumption in the Textile Industry Data for 1990

Sector/Subsector	Output & Unit	Energy Consumed: Fuel (10^6 Tsc equiv.): Standard Coal 10^6 T	Oil 10^6 T	Gas 10^9 M^3	Steam 10^9 Kj	Total 10^6 Tsc	Electricity: 10^6 KWH	10^3 Tsc	Total Energy 10^6 Tsc
Chemical Fibers	1.65 * 10^6 T	2.63	0.09 (0.13)		8,450 (0.288)	3.0048	4,192	1,593	4.747
Cotton Yarn/ Fabric	4.62 * 10^6 T	4.13	0.109 (0.155)	0.019 (0.0006)	14,450 (0.493)	4.784	13,510	5,458	10.242
Wool Yarn/ Fabric	295 * 10^6 *	1.54	0.049 (0.070)	0.00263 (0.0009)	5,034 (0.171)	1.781	1,173	413	2.194
Printing/ Dyeing	9.10 * 10^9 M	2.04	0.035 (0.121)	0.039 (0.0317)	14,194 (0.484)	2.676	1,008	407	3.083
Silk Textiles	1.70 * 10^9 M	1.44	0.061 (0.087)	0.00176 (0.0006)	1,771 (0.060)	1.587	1,030	416	2.003
Garments Footwear Headwear	8 * 10^9 pcs	0.31	0.011 (0.015)			0.321	278	112	0.433
Others		3.12	0.075 (0.107)	0.00761 (0.0027)	4,040 (0.187)	8.866	2,109	852	3.897
Total		15.21 (15.21)	0.48 (0.685)	0.12 (0.0428)	47,940 (1.635)	17.572	23,300	9,413	26.985
Conversion Factor		1	1.4286	0.3571	0.03412		0.404		

( ) Converted to Standard Coal.

energy saving and on the technologies used by the industry. Systems of incentives and penalties have been introduced, and awareness campaigns conducted.

Table 3.32: ENERGY CONSERVATION MEASURES

Projects	(Y 100 m)	Coal equiv. (10kt)	Raw coal (10kt)	Electricity (100 GWh)	Oil (10 kt)	Energy saving value (Y 100 m)	Investment for unit energy saving (tce)	Return period (Year)
Cogeneration (supply)	70	950	1,330	-	-	14.25	737	4.91
New type of burner for coal powder boiler	1.35	139	174	-	10.8	2.9	97	0.47
Boiler sealing for heat protection	2.4	85	119	-	-	1.28	282	1.88
Water pumper speed adjusting	10	120	-	30	-	7.5	833	1.33
Comprehensive innovation for unit of 0.2 MkW	15	220	308	-	-	3.3	682	4.55
Washing steam-condenser by rubble ball	0.5	160	224	-	-	2.4	31	0.21
Motor innovation of magnetic slot	0.08	15.2	-	3.8	-	0.95	52.6	0.084
Surplus heat recycling of pipe heat exchanging	8.2	403	465	17.79	-	9.46	230	0.87
Microcomputer online analysis for energy loss	4	350	490	-	-	5.25	114	0.76
Improving for nonpower compensation	12	80	-	20	-	5	1,500	2.4
Innovation on electricity distribution of urban area	22.8	348	-	87	-	21.75	625	1.05
Total	146.33	2,870.2	3,950	158.59	10.8	74.04	782	1.94

Note: (1) Thermal supply is not included in thermal power cogeneration.
(2) Energy prices apply the shadow price: Y 150/tce, Y 0.25/kWh, Y 930/t. Investments are calculated with fixed prices.
(3) The investments and energy saving are forecasted based on the average results of the complete projects.

3.181 With respect to investments for energy efficiency in the period 1980-90, over 2200 projects were authorized with a total investment of over Y 700 million, with anticipated energy savings of 1.2 million TCE/yr. Examples of projects are:

(a) Cogeneration. One hundred one projects built or under construction for a total investment of over Y 300 million. Anticipated savings are 0.6 million TCE/yr and electricity generation capacity will total 0.4 million kW.

(b) Steam distribution. More than 600 projects have been completed or scheduled to update old steam systems, with a total investment of Y 200 million.

(c) Air conditioning. Typically, this requires 15 to 20 percent of site energy consumption for dust removal and the control of temperature and humidity. Various improvements are being made, such as blower renewal, lower water pumping rates, variable speed operation, LiBr systems, and new air conditioners.

(d) **Motors and transformers.** These are being replaced with modern equipment to achieve lower power factors and lower electricity consumption. High efficiency motors are used in most spinning machines.

(e) **Increased use of coal.** Energy distribution by hot air and hot oil, heated by coal fired equipment, is being used to replace electricity or fuel oil systems.

Other measures include attention to water consumption and to routine maintenance.

Potential for Improvements in Energy Efficiency

3.182 The potential for energy efficiency improvement is significant. There are, of course, many factors such as process route, size of production facilities, range of products, and climate. However, the specific energy consumption for chemical fibre production is generally higher than in developed countries, although for natural products, it is usually lower. Average figures for the Chinese industry and typical developed country data are as follows:

	China		Typical overseas	
	Electricity kWh/t	Fuels TCE/t	Electricity kWh/t	Fuels TCE/t
Viscose staple fibers	1,999	2.28	1,020/1,470	0.82/1.28
Viscose filament fibers	10,439	9.17	3,700	4.08
Polyester staples	749	0.72	586	0.8
Polyester filaments	2,678	0.63	830/1,030	0.4/1.28
Nylon fibers	3,564	1.47	4,900	2.0
Acrylic fibers	1,540	4.99	1,000	3.0
Vinylon	2,291	2.34	2,100	1.2
Cotton yarns	2,129	-	3,458	-
Cotton fabrics	25 kWh/100 m	-	39 kWh/100 m	-
Dyed, printed fabrics		- 43 kg/100 m		50 kgCE/100 m

3.183 Energy consumptions in developed countries have risen in recent years as their textile industries have adopted higher speed machines and automated operations to save manpower and cut costs. Also, many products are made in small batches with various specifications to meet rapidly changing markets. Standards for space conditioning and dust removal are generally higher than in China (e.g., 30 to 50 percent of site energy use versus 15 to 20 percent in China). These factors add to energy use in the developed countries, although this has been offset to a large extent in the chemical fibers industries by introduction of energy efficient technologies in large-scale chemical plants.

3.184 For the future, savings in the Chinese textile industry are expected to be achieved by improvements in processes and better management. Some typical technical renovations which are expected to be accomplished by 2000 are as follows:

Item	Capacity	Investment 10^9 RMB	Energy saving 10^2 TCE/y
Cogeneration	0.4 10^6 kWh	1.0	1,000
Boiler renewal	12,000 t steam/h	1.2	900
Motor renewal	0.3 10^6 kWh	0.2	40
Air conditioning improvement	3,000 sets	0.2	1,200
Chiller improv.	200 sets	0.1	60
Water supply	200 sets	0.2	600
Others		0.6	280

Projected Industry Outputs and Energy Consumption

3.185 The share of chemical fibers in the industry output is expected to grow from 20 percent in 1990 to 33 percent in 1995 and 39 percent in 2000. It is expected that more productive machinery will be increasingly adopted—e.g., open-end spinning machines to 0.6 million and shuttleless looms to say 5 to 6 percent. Although this may increase energy consumption in the industry, the output will be increased more and the specific energy consumption will be lower. Electronic controls will be more widely used. The products of the industry will show more variety and will have a higher value added.

3.186 Forecasts of industry output have been made as follows:

	1995	2000	2010	
Total output value	196	269	350	10^9 RMB
Export value	15	20	35	10^9 USD
Processed fibers	7.8	9.0	11.0	10^6 tons
Chemical fibers	2.1	3.0	5.0	10^6 tons
Cotton yarns	5.66	6.47	7.27	10^6 tons
Wool fabrics	320			10^6 meters
Silk fabrics	2.5			10^9 meters
Garments	5.0			10^9 pieces

3.187 Forecasts of industry energy consumption are as follows:

(10^6 TCE)	1990	1995	2000	2010
Chemical fiber production	4.75	5.94	8.55	10.45
Textile production	20.53	30.80	36.96	48.25
Garments, footwear,headwear	0.45	0.72	1.00	1.06
Other production	1.47	2.20	2.64	2.94
Total	27.20	39.66	49.15	62.70

Generic Investment Options

3.188 Three measures were selected for detailed examination as case studies, each with good potential for wide replication in the textiles industry:

(a) **T1 Cogeneration.** The textiles industry is similar in many ways to the paper industry in that it uses large amounts of both electricity and steam. While essentially all plants produce their own steam, only a few generate their own electricity. The on-site generation of both steam and electricity in modern cogeneration systems will raise energy efficiency, and thus reduce greenhouse gas emissions, by replacing old and obsolete equipment and by introducing a process that is inherently more efficient than separate generation.

(b) **T2 Caustic soda recovery.** Caustic soda is used in many textile mills for treating cloth prior to dyeing or printing to improve the dye absorption and lustre of the finished material. Most plants do not recover the caustic soda from the dilute spent solution and this is therefore discharged to waste water treatment facilities. These are often unable to effect proper treatment and contaminated water may then be dumped into local rivers. Recovery of the caustic soda from dilute spent solutions by a multiple effect evaporator system would reduce water pollution significantly and reduce the need for purchasing fresh chemicals. In this way, the demand for caustic soda could be reduced and the corresponding energy saved.

(c) **T3 Computerized energy management systems.** The operations at many textile mills are relatively complex and good energy management requires a variety of parameters to be checked regularly. Adoption of computerized data collection and analysis systems can assist management to detect adverse trends in efficiency promptly and thus to make appropriate adjustments to key operating conditions in a timely manner. Such systems are of course applicable throughout manufacturing industry and could show major benefits well beyond the textiles sector.

3.189 Based on data obtained on each of these measures from actual plants in China, the following rates of return and payback were estimated. The results—with the payback period including the time taken for construction—are as follows:

	IRR %	Payback, years
T1 Cogeneration	37.6	6
T2 Caustic soda recovery	57.9	3
T3 Computerized e. mgmt.	-	-

3.190 Based on the characteristics of the textiles sector and taking into account the potential for applying the measures listed, forecasts for adoption under business as usual and accelerated scenarios were made. These were expressed in terms of million meters of fabric per year, by referring the required cogeneration capacity to an actual plant processing a known amount of fabric annually (and which has already invested in a cogeneration system). A similar argument was used for estimating the extent of caustic soda recovery and of energy management system computerization. The forecasts are as follows:

	1990	2000	2010
		(million meters/yr)	
T1 Cogeneration			
BAU without cogeneration	30,000	25,200	6,000
with cogeneration	0	4,800	24,000
Accel. without cogeneration	30,000	22,800	3,000
with cogeneration	0	7,200	27,000
T2 Caustic Soda Recovery			
BAU without recovery	30,000	25,000	3,000
with recovery	0	5,000	27,000
Accel. without recovery	30,000	21,000	0
with recovery	0	9,000	30,000
T3 Computerized Energy Management			
BAU without computer system	30,000	22,500	0
with computer system	0	7,500	30,000
Accel. without computer system	30,000	18,000	0
with computer system	0	12,000	30,000

Further details of the energy and emissions factors used for the calculations are given in Appendix A.

Impacts on Energy and Emissions

3.191 Using the forecasts indicated above, the impact of the various measures on energy consumption in the textiles sector was estimated as follows:

	Savings 10^3 TCE/yr by 2000		Savings 10^3 TCE/yr by 2010	
	BAU	Accel.	BAU	Accel.
T1 Cogeneration	290.9	436.3	1,454.4	1,636.2
T2 Caustic recov.	50.7	91.3	273.8	304.2
T3 Computer e.m.	53.0	84.8	212.1	212.1

With respect to greenhouse gas emissions, the reductions in CO_2 were forecast as follows:

	CO_2 reduction 10^3 TPY by 2000		CO_2 reduction 10^3 TPY by 2010	
	BAU	Accel.	BAU	Accel.
T1 Cogeneration	211.8	317.6	1,058.8	1,191.1
T2 Caustic recov.	32.3	58.1	174.4	193.7
T3 Computer e.m.	35.2	56.3	140.8	140.8

Emissions

3.192 Pollutants emitted by the textiles industry are as follows:

(a) Wastewater. About 750 million tons need to be treated annually, of which 80 percent is from printing and dyeing. It is estimated that 67 percent is treated (1990) and 72 percent of printing/dyeing waste water is treated to meet the national discharge standards.

(b) Waste gases. These are mainly the 228 billion cubic meters of combustion gases emitted from the burning of 22 million tpy coal in boilers, containing 387,200 t of SO_2, 44 million t of CO_2 and 200,000 t of nitrogen oxides:

123,200 t of particulates are also emitted. The textile industry (excluding TVEs) operates almost 18,000 boilers with a total steam raising capacity of about 55,000 t/h.

(c) **Solid wastes.** These are mainly the ashes and slags from coal burning boilers, amounting to about 5.5 million tpy. This material is used in rural areas for road building and brick making. Any waste industrial material is either sold or buried.

3.193 It is recognized that proper combustion control is necessary to reduce emissions of carbon particles (unburned fuel) and dust, and to reduce carbon dioxide production by using less fuel. Most boilers are now fitted with dry or wet dust removing equipment.

F. CHEMICALS

Industry Profile and Products

3.194 The growth of the chemical industry since 1949 has been substantial. In the 1970s, as petroleum and natural gas production expanded, major chemical plant construction included 13 large ammonia plants and one large ethylene plant (300,000 tpy capacity): these were built using imported technology. During the Sixth and Seventh Five-Year Plans (1976 to 1985), a large number of chemical plants were built and major production sites developed, mainly using locally-based technologies and some imported equipment. The rate of development of the chemical industry was higher than most other branches of industry until about 1970. Growth rates and output value indices are presented in Table 3.33.

3.195 The Chinese chemical industry is very diverse and manufactures over 30,000 different products, many based on coal as a fuel and feedstock, others on oil or natural gas. For some items, such as chemical fertilizers, sulphonates, caustic soda, calcium carbide and synthetic rubber, China ranks amongst the largest producers in the world. Output data for major products are given in Table 3.34.

3.196 There are over 20 subsectors of the chemicals industry—important ones include mining of chemical products, synthetic fertilizers, inorganic and organic basic chemicals, plastics and similar synthetic materials, fine chemicals, petrochemicals, synthetic rubber and rubber articles, and the production of chemical plant machinery. Numbers of enterprises and output values for various subsectors are shown in Table 3.35.

3.197 There are now more than 6,500 enterprises in the chemical industry, divided into large, medium and small-scale plants according to capacity or total fixed assets. Table 3.35 shows the chemical industry consisted of 3.5 percent large plants, 10.1 percent medium and 86.4 percent small plants in 1990. Many of the large and medium enterprises were built in the late 1970s, although some date from the 1950s. The proportion of large and medium plants has risen from about 4 percent in the late 1970s to about 13 percent by

Table 3.33: OUTPUT VALUE INDICES AND GROWTH RATES FOR THE CHEMICALS SECTOR AND THE INDUSTRIAL SECTOR

Year/period	Output index: Chemical sector	Output index: Total industry	Annual growth rate: Chemical sector	Annual growth rate: Total industry
1952	100.0	100.0		
1950-52			60.8	34.8
1953	131.8	130.3		
1954	172.3	151.6		
1955	190.7	160.0		
1956	285.9	204.9		
1957	353.6	228.6		
1953-57			28.7	18.0
1958	678.4	353.0		
1959	956.8	481.7		
1960	1,139.0	535.7		
1961	727.5	330.3		
1962	632.4	276.0		
1958-62			12.3	3.8
1963	745.2	299.4		
1964	947.4	358.1		
1965	1170.8	452.8		
1963-65			22.8	17.9
1966	1,502.0	547.4		
1967	1,362.8	471.8		
1968	1,282.3	448.1		
1969	1,889.1	601.6		
1970	2,243.0	793.1		
1966-70			13.1	12.0
1971	2,662.3	915.3		
1972	2,971.5	978.2		
1973	3,284.2	1,071.2		
1974	3,103.8	1,077.7		
1975	3,672.5	1,244.7		
1971-75			10.4	9.3
1976	3,612.5	1,274.9		
1977	2,488.7	1,461.1		
1978	4,980.4	1,659.0		
1979	5,354.1	1,805.3		
1980	5,643.5	1,972.3		
1976-80			9.0	9.6
1981	5,611.3	2,057.2		
1982	6,186.8	2,217.8	10.3	7.8
1983	6,926.2	2,465.9	12.0	11.2
1984	7,509.9	2,867.4	8.4	16.3
1985	7,916.7	3,480.9	5.4	21.4
1981-85			7.0	12.0
1986	8,521.7	3,887.0	7.6	11.7
1987	9,794.5	4,574.7	14.9	17.7
1988	11,064.2	5,525.6	12.9	20.8
1989	11,742.7	5,997.3	6.1	8.5
1990	12,428.5	6,465.1	5.8	7.8
1986-90			7.8	13.2

Table 3.34: Output of Selected Chemical Products

All figures expressed as thousand tons per year

Year	Selected Ores: FeS Ore 35%	Selected Ores: Phosphor. Ore 30%	Acids: Sulfuric Acid	Acids: Nitric Acid	Acids: HCL	Caustic Soda 100 pct	Sodium Carbonate (Soda ash)	Chemical Fertilizers: Nitrogen fert. (N)	Chemical Fertilizers: Phosphor. Fert (P)	Chemical Fertilizers: Potassium Fert. (K)	Chemical Fertilizers: Total	Ammonia	Calcium carbide (300 l/kg acetylene)	Carbon black
1981	5,880	10,860	7,807	184	1,296	1,923	1,652	9,857	2,508	26	12,391	14,834	1,513	144
1982	6,190	11,730	8,174	246	1,483	2,073	1,735	10,218	2,537	25	12,780	15,464	1,564	164
1983	7,350	11,630	8,695	256	1,583	2,123	1,793	11,094	2,665	29	13,788	16,671	1,807	190
1984	8,010	14,210	8,172	258	1,704	2,222	1,880	12,211	2,359	31	14,601	18,371	1,846	223
1985	6,820	6,970	6,715	274	1,856	2,349	2,009	11,439	1,758	21	13,218	16,409	1,933	247
1986	7,830	9,790	7,630	275	2,059	2,158	2,144	11,588	2,325	25	13,938	16,579	2,147	280
1987	10,550	14,870	9,830	290	2,270	2,735	2,334	13,422	3,239	40	16,701	19,392	2,391	290
1988	11,160	18,220	11,112	302	2,462	2,978	2,619	13,608	3,607	53	17,268	19,793	2,253	290
1989	12,200	19,980	11,526	412	2,570	3,208	3,029	14,240	3,663	32	17,935	20,691	2,460	320
1990	12,740	21,550	11,969	318	2,023	3,352	3,793	14,637	4,116	46	18,799	21,290	2,281	327

Table 3.35: CHEMICAL SECTOR ENTERPRISES AND OUTPUT VALUES

	1990			1991	
	Number of enterprises	(%)	Output value Y 10^9	Number of enterprises	Output value Y 10^9
Total	6,668		1,394.3	6,564	1,519.3
Large scale	232	(3.5%)	477.7	253	561.9
Middle scale	672	(10.1%)	365.2	755	405.6
Small scale	5764	(86.4%)	551.4	5,556	551.8
Mining	205	(3.1)	18.1	202	20.0
of which, sand/stones	2		0.1	2	0.1
Chemical ores	203		18.0	200	19.9
Basic chem. materials	1,065	(16.0)	234.4	1,044	237.6
Chemical fertilizers	1,775	(26.6)	344.8	1,737	368.8
of which, N fert.	1,093		263.0	1,052	273.7
Small ammonia	1,033		167.4	993	173.4
P fertilizer	592		78.1	573	96.2
K fertilizer	1		0.1	1	0.1
compound fertil.	89		3.7	111	8.8
Chemical pesticides	210	(3.1)	64.1	333	75.4
Organic chemicals	1,329	(19.9)	297.6	1,307	337.1
of which, basic mat.	325		105.5	323	126.5
Paint, pigments	343		79.5	338	89.2
Colorants	100		36.2	97	38.3
Chemical reagents	88		8.9	88	9.0
Catalysts	266		38.1	267	43.8
Adhesives	27		1.9	267	43.8
Magnetic materials	16		2.5	11	1.5
Miscellaneous	164		25.1	159	26.7
Synthetic materials	106	(1.6)	39.8	112	58.4
Light sensitive materials	8	(0.1)	4.8	7	5.6
Rubber products	1,049	(15.7)	290.1	1,015	308.2
Chemical machinery	245	(3.7)	23.8	238	26.0
Others	676	(10.1)	76.8	680	82.2

the late 1980s. The fertilizer enterprises represented 26.6 percent of the total number of enterprises (the largest category), with other major subsectors being organic chemicals (19.9 percent of enterprises), basic chemicals (16 percent) and rubber processing (15.7 percent).

3.198 The smaller plants are very widely distributed: for example, almost every county has a fertilizer plant. Larger plants are located in areas with greater industrial concentrations and good technical support. The location of enterprises and the distribution of output values are given in Table 3.36 and summarized in Table 3.37.

3.199 The annual output of fertilizers has been around 18-19 million tons in recent years. The output of nitrogen fertilizer is over 14.5 tpy, about 80 percent of the total production, within which urea makes up 33 and ammonium bicarbonate 60 percent (Table 3.38). The raw material for nitrogen-based fertilizers is synthetic ammonia, the output of which is about 20 million tpy, 22 percent from medium-scale plants, 22 percent from large plants and 56 percent from small plants. A variety of feedstocks are used but more than half the ammonia is made from coal (see Table 3.39).

3.200 The annual output of phosphorous fertilizer—mainly calcium phosphate and calcium magnesium phosphate—has been around 4 million tons in recent years, or about 20 percent of fertilizer production. The output of ammonium phosphate has been increasing and is now about 3 percent of phosphorous fertilizer production. The trend is towards a greater proportion of phosphorous fertilizer in the total chemical fertilizer production.

3.201 There is relatively little production of potassium-based fertilizers. The annual output is only about 30-40,000 tons, 0.2 percent of fertilizer production.

3.202 Another basic material is sulfuric acid, the annual output of which has been 11-12 million tons recently, about 82 percent of which is typically made from pyrites, 15 percent from smelter gas and 3 percent from raw sulphur. Various grades of sulfuric acid and related products are made, such as high concentrate oleum, battery acid and liquid SO3. Oleum production is about 350,000 tpy and liquid sulfuric acid about 40,000 tpy. Some plants still produce ammonium bisulphite, ammonium sulphite and liquid SO_2.

3.203 Caustic soda manufacture is important and output has been increasing in recent years to around 3 to 3.4 million tpy. A number of technologies are used, such as electrolysis by the diaphragm or mercury cathode process: about 90 percent of caustic soda is now made by the diaphragm electrolysis route. In 1988, China imported a 10,000 tpy plant for making caustic by the ion-exchange membrane process. This uses less energy and gives high quality product with less pollution. Caustic soda output by this technology has now reached about 300,000 tpy and is expected to increase.

3.204 The output of soda ash exceeded 3 million tpy in 1989, of which about 70 percent was made in eight large plants and the remainder in small or medium-scale plants. It is expected that the proportion made in the larger plants will increase—three plants with capacity of 600,000 tpy each are to be brought on-line soon. The processes used are the ammonia-soda route and the joint process, the former representing about 56 percent of the present production after commissioning the new plants.

Table 3.36: CHEMICALS ENTERPRISES AND OUTPUT VALUES BY LOCATION

	1990		1991	
	No. of enterprises	Gross output value 10^9 Y	No. of enterprises	Gross output value 10^9 Y
Total	6,668	1,394.3	6,564	1519.3
Beijing	38	49.0	38	50.4
Tianjin	209	58.1	210	58.8
Hebei	442	72.4	432	80.5
Shanxi	245	36.7	230	38.0
Neimeng	137	13.5	137	14.1
Liaoning	489	100.3	512	107.0
Jilin	244	66.5	171	68.7
Heilongjiang	218	36.2	236	38.4
Shanghai	235	108.8	225	117.6
Jiangsu	446	125.9	443	137.1
Zhejiang	239	60.8	232	70.5
Anhui	252	38.1	254	42.2
Fujian	142	28.3	142	31.6
Jiangxi	171	18.7	159	19.7
Shandong	455	125.7	465	138.5
Henan	395	63.4	371	75.0
Hubei	313	60.8	328	65.6
Hunan	349	54.7	346	60.3
Guangdong	324	64.8	325	77.9
Guangxi	142	24.2	138	25.9
Hainan	14	2.2	14	2.5
Sichuan	376	81.2	380	87.3
Guizhou	125	21.1	113	22.7
Yunnan	198	32.0	199	34.7
Xizhang	1	--	1	--
Shaanxi	169	20.2	159	21.5
Gansu	84	11.0	88	1.8
Qinghai	29	2.7	29	2.6
Ningxia	41	8.6	46	9.0
Xinjiang	146	8.5	141	9.6

Table 3.37: SHARE OF CHEMICALS OUTPUT BY REGION

Percentages of national output	1987	1988	1989	1990
Eastern coastal /a	58.6	58.4	57.8	58.0
Central inland /b	34.1	34.2	34.5	33.9
West region /c	7.3	7.4	7.7	8.1

/a Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangzhou, Hainan, Tianjin, Beijing, Shanghai.
/b Heilongjiang, Jilin, Shanxi, Shaanxi, Anhui, Jianxi, Henan, Hubei, Hunan, Sichuan.
/c Neiming, Ningxia, Gansu, Qinghai, Xinjiang, Xizhang, Yunnan, Guizhou, Guangxi.

3.205 The output of calcium carbide is now about 2.3 million tpy, more than half produced by small furnaces. It is not expected that carbide production will increase in future.

Energy Use

3.206 For fuels, electricity and feedstocks, the chemical industry consumes around 90 million TCE of energy every year, representing about 9 percent of the national energy consumption. Energy use is increasing at 2-3 percent each year. Figures for energy use by type of energy and by subsector of the industry are presented in Table 3.40. As indicated in this table, the chemical industry uses a large amount of energy resources as feedstock (over one third of total consumption of energy products). A detailed breakdown of energy use by industry subsectors and by type of energy source is given in Table 3.41.

3.207 The variation in energy consumption across more than 6,500 enterprises is of course very large. However, many of the plants are small and there are relatively few which can be considered large energy consumers. The following approximate figures are available:

Annual consumption	< 20,000 TCE	say 4,700 enterprises
	> 20,000 TCE	say 2,000
	> 50,000 TCE	say 200

3.208 Steam is used widely in the chemical industry as a heating medium, a raw material and as a means of producing electricity. About 150 million tpy are used—80 million for processes, 30 for heating and 40 for electricity generation. With respect to

Table 3.38: COMPOSITION OF FERTILIZER PRODUCTS

	Production 10^6 t	Percent of total	Percent of each type
Nitrogen fertilizer			
Ammonium sulphate	0.104		0.7
Ammonium nitrate	0.579		4.0
Urea	4.885		33.4
Ammonium chloride	0.387		2.6
Ammonium bicarbonate	8.480		58.0
Urea solution	0.071		0.5
Other	0.126		0.9
Subtotal	14.632	77.9	100.0
Phosphorous fertilizer			
Calcium phosphate	2.891		70.2
NPK fertilizer	0.975		23.7
Ammonium phosphate	0.110		2.7
Other	0.140		3.4
Subtotal	4.116	21.9	100.0
Potassium fertilizer	0.046	0.2	
Total	18.794	100.0	

electricity, 63 billion kWh are consumed annually, with a very rough breakdown estimated as follows:

	10^9 kWh
Process (e.g., electrolytic)	5
Air compression	7
Pumping	20
Ammonia compressors	11
Lighting, maintenance	3
Heating, all other uses, losses	17
Total	63

Table 3.39: FEEDSTOCK FOR AMMONIA PRODUCTION, 1990

	Quantity 10^6 t	Percent
Anthracite	11.598	52.6
Coke	0.933	4.2
Coke from TVE's	0.909	4.1
Brown coal	0.600	2.7
Heavy oil	2.200	10.0
Natural gas	3.610	16.4
Oilfield gas	0.238	1.1
Coke oven gas	0.230	1.0
Refinery gas	0.081	0.4
Light oil	1.641	7.4
Others	0.014	0.1
Total	22.054	100.0

3.209 Energy consumption data for the manufacture of major products are presented in Table 3.42 in terms of total energy and specific energy consumptions.

3.210 Part of the energy consumed by the chemical industry is provided by government (the "planned" amount) and some must be purchased on the open market. Prices can vary considerably: for example, the price of heavy oil in late 1992 was about Y 200 per ton for "plan" oil but around Y 480/t on the open market. The insufficiency of supply of natural gas and oil fuels is particularly acute, with the potential demand being satisfied to an extent of only about 60-80 percent. Only about 80 percent of potential electricity demand is met. Even the demand for coal cannot be met due to serious limitations on coal transport.

Table 3.40: ENERGY CONSUMPTION IN THE CHEMICAL INDUSTRY

	1985-90		1988		1989		1990	
	10^6 TCE	Percent	10^6 TCE	Percent	10^6 TCE	Percent	10^6 TCE	Percent
Primary energy use excl. electricity	210.98	51.0	44.10	52.2	45.83	52.0	46.67	52.1
Energy as feedstock	152.78	36.9	30.96	36.7	32.22	36.6	32.03	35.8
Subtotal	363.76	88.0	75.06	88.9	78.05	88.6	78.70	87.9
Electricity	49.80	12.0	9.35	11.1	10.04	11.4	10.86	12.1
Total	413.56	100.0	84.41	100.0	88.09	100.0	89.56	100.0
Share of national energy use		9.2		9.2		9.2		9.1
By energy type								
coke and purchased steam	237.10	57.3	49.36	58.5	51.00	57.9	50.57	56.5
oil fuels	23.85	5.8	4.50	5.3	4.88	5.5	5.06	5.6
gas	30.66	7.4	5.90	7.0	6.70	7.6	6.09	6.8
electricity	115.29	27.9	22.94	27.2	23.85	27.1	24.50	27.4
other	6.66	1.6	1.71	2.0	1.66	1.9	3.34	3.7
Total	413.56	100.0	84.41	100.0	88.09	100.0	89.56	100.0
By subsector								
chemical mines	3.71	0.98	0.64	0.8	1.38	1.6	0.79	0.9
basic chemicals	68.70	16.6	13.66	16.2	13.73	15.6	14.99	16.7
fertilizers	249.53	60.3	52.76	62.5	53.36	60.6	51.97	58.0
of which, N fertilizers	290.58	55.8	48.61	57.6	49.25	55.9	48.07	58.7
pesticides	5.91	1.4	1.20	1.4	1.30	1.5	1.35	1.5
organic chemicals	49.91	12.1	10.84	12.8	10.73	12.2	11.45	12.8
rubber products	13.56	3.3	2.61	3.1	2.85	3.2	2.91	3.2
chemical machinery/equipment	1.17	0.3	0.24	0.3	0.24	0.3	0.23	0.3
other	21.07	5.1	2.46	2.9	4.50	5.1	5.87	6.6
Total	413.56	100.0	84.41	100.0	88.09	100.0	89.56	100.0

Table 3.41: ENERGY RESOURCE CONSUMPTION IN 1990 (I)

The whole nation

Measured unit: ton

Name	Enterprise unit number	Raw coal: Sub-total	Raw coal, among which: Anthracite	Raw coal, among which: Bought outer briquet	Raw coal, among which: Bituminite coal	Raw coal, among which: Lignite	Coal by coking: Sub-total	Coal by coking: Washed refined coal	Coal by coking: Other washed coal	Coke: Sub-total	Coke: among which: self-supply & use	Coke: among which: machine coke	Coke: among which: self-supply & use	Crude oil sub-total	Heavy oil: Sub-total	Heavy oil: among which: self-supply & use
First	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Total	4,395	55,020,073	25,912,997	34,978	27,897,254	1,174,848	5,109,629	4,339,682	174,188	7,368,278	858,188	1,358,788	557,878	199,254	3,044,223	511,957
2. Large sized enterprise	210	10,583,481	1,757,518	8	8,657,251	168,650	3,655,141	3,655,018	56,254	2,232,423	634,391	1,652,277	550,878	129,418	1,727,829	478,548
3. Medium sized enterprise	589	11,182,932	3,410,043	27	7,182,012	899,850	832,151	533,853	29,089	1,843,598	2,558	128,294	0	33,759	824,117	0
4. Small sized enterprise	3,587	33,273,680	20,745,438	34,943	12,087,951	405,348	622,337	150,793	88,823	3,292,258	21,242	178,217	0	38,077	293,077	3,419
5. Chemical industry raw material total	1,758	24,454,372	22,245,824	5,843	2,007,400	195,765	209	0	48,785	8,434,309	578,398	1,117,222	517,249	188,908	1,253,257	299,280
6. Non-metallic mining	185	423,578	91,238	0	332,310	29	4,530	4,494	0	110,731	0	1,048	0	14	1,983	0
7. among which: soil-sand stone mining	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8. Chemistry mining	183	423,578	91,238	0	332,310	29	4,530	4,494	0	110,731	0	1,048	0	14	1,983	0
9. Elementary chemical raw material industry	628	8,109,801	1,328,481	1	878,610	70,508	317,381	317,381	59,331	1,295,497	168,088	581,768	168,888	16,100	253,661	4,770
10. Fertilizer industry	1,621	36,676,789	23,842,068	25,644	1,209,773	713,341	1,072,487	1,002,009	79,392	5,248,992	1,940,171	395,354	172,523	1,326	811,944	5,842
11. among which: nitrogen fertilizer industry	1,075	35,286,738	23,205,303	25,442	1,138,074	892,244	894,702	824,349	75,075	3,913,724	157,142	284,980	133,345	1,297	805,944	5,842
12. Small nitrogen fertilizer industry	1,017	28,583,210	20,326,359	25,442	720,011	238,298	258,087	185,734	72,255	1,713,953	23,797	55,178	0	1,097	195,887	642
13. Phosphate fertilizer industry	508	1,375,182	638,477	202	70,883	20,887	177,785	177,660	1,802	1,335,204	39,175	113,394	39,175	18	65,998	0
14. Potash fertilizer industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. Compound fertilizer industry	33	14,869	288	0	10,351	230	0	0	2,515	84	0	0	0	7	0	0

Table 3.41: cont'd

The whole nation

Measured unit: ton

Name	Enterprise unit number	Raw Coal: Sub-total	Raw Coal: Among which: Anthracite	Raw Coal: Among which: Bought outer briquet	Raw Coal: Among which: Bituminite coal	Raw Coal: Among which: Lignite	Coal by coking: Sub-total	Coal by coking: Washed refined coal	Coal by coking: Other washed coal	Coke: Sub-total	Coke: among which: self-supply & use	Coke: among which: machine coke	Coke: among which: self-supply & use	Crude oil sub-total	Heavy oil: Sub-total	Heavy oil: among which: self-supply & use
First	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16. Chemical pesticide industry	169	878,272	135,781	0	710,863	14,648	0	0	900	18,322	0	4,166	0	8	1,654	0
17. Organic chemical products industry	732	4,413,896	183,831	394	4,024,083	205,612	618,142	618,142	4,796	358,376	216,468	252,262	216,468	171,159	811,850	450,509
18. among which: organic chemical raw material industry	217	2,157,428	83,129	4	2,010,149	55,150	482,494	482,494	0	323,914	216,468	244,057	216,468	21,474	407,212	400,387
19. Coating and pigment industry	173	499,839	41,874	0	463,574	7,591	2,585	2,585	0	13,066	0	1,901	0	8,854	81,469	0
20. Dyestuff industry	61	633,098	19,355	269	590,018	19,858	0	0	0	5,532	0	5,204	0	0	10,901	0
21. Chemical reagent industry	29	50,532	0	0	50,532	0	3,092	3,092	0	277	0	0	0	0	0	0
22. Catalyst and sort of chemical auxiliary industry	148	833,512	27,521	107	500,621	105,263	149,971	149,971	4,798	15,587	0	1,700	0	140,592	222,509	2,261
23. Adhesive industry	13	12,375	1,771	0	11,804	0	0	0	0	0	0	0	0	99	0	0
24. Magnetic record material industry	9	8,743	0	0	743	0	0	0	0	0	0	0	0	0	334	0
25. Other organic chemical products industry	82	418,369	10,381	14	390,024	17,950	0	0	0	0	0	0	0	140	79,425	3,512
26. Synthesis material industry	76	500,059	31,935	4,850	468,274	0	2,414	2,414	0	113,709	0	11,453	0	0	81,241	24,281
27. Light sensitive material industry	8	30,272	0	0	30,272	0	0	0	0	0	0	0	0	0	6,327	0
28. Rubber products industry	528	2,781,751	249,487	4,038	2,383,021	185,225	15,053	15,053	24,122	409	0	179	0	943	85,215	0
29. Chemical engineer mechanical industry	168	119,542	7,781	27	108,580	5,154	0	0	7	12,701	0	4,911	0	1,022	10,022	0
30. Other industry	302	1,086,313	44,435	24	1,041,521	338	3,079,622	2,380,819	5,618	209,612	76,515	105,047	0	8,688	140,330	27,777

Table 3.41: cont'd

The whole nation

Measured unit: ton

Name	Gaso-line sub-total	Kero-sene sub-total	Diesel sub-total	Liqui-fied petro-leum gas	Oil refinery plant dry gas		Natural gas (ten thousand cubic meter)	Coke oven gas (ten thou. cubic meter)		Bought outer vapor	Electricity power (ten thousand kWh)		Other energy resource (ton normal coal)				Total
					Sub-total	Among which: self-supply & use		Sub-total	Among which: self-supply & use		Sub-total	Among which: self-supply & use	Sub-total	Among which: Other coal gas	Other petrol products	Other pyro products	
Second	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1. Total	470,209	20,324	181,140	22,319	111,733	94,440	474,448	212,527	105,854	20,541,934	8,375,455	311,673	1,321,871	26,427	855,173	298,969	89,581,973
2. Large sized enterprise	141,173	14,183	87,259	270	78,284	76,284	332,448	185,880	94,095	15,019,638	2,042,895	257,142	983,480	19,618	555,171	143,112	3,129,022
3. Medium sized enterprises	128,784	1,599	33,924	17,322	1,942	0	24,808	22,854	8,194	3,943,388	1,385,007	31,848	246,363	3,459	39,845	114,850	17,437,015
4. Small sized enterprise	199,732	4,541	59,957	4,727	33,507	18,058	117,184	3,993	3,585	1,578,913	3,027,873	22,606	112,023	3,352	80,158	41,007	40,834,700
5. Chemical raw material total	167,485	12,730	5,774	149	0	0	382,770	43,870	18,873	909,912	245,485	2,131	1,036,847	3,828	570,908	181,395	32,033,540
6. Non-metallic mining	21,252	33	20,379	0	0	0	0	0	0	0	78,089	4,314	0	0	0	0	785,525
7. Among which: soil-sand stone mining	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0	0	274
8. Chemistry mining	21,252	33	20,379	0	0	0	0	0	0	0	78,001	4,014	0	0	0	0	785,251
9. Elementary chemical raw material	47,618	2,887	38,575	13	0	0	17,815	8,103	0	5,383,035	1,806,288	133,015	51,297	8,485	7,698	7,915	14,988,070
10. Fertilizer industry	148,112	1,027	70,258	218	0	0	435,234	48,363	18,758	4,094,746	3,451,876	136,508	51,597	3,449	18,985	278	51,985,556
11. Among which: nitrogen fertilizer	122,502	772	58,052	124	0	0	434,040	48,363	18,758	3,188,928	3,141,183	116,467	51,353	3,449	18,985	278	48,070,428
12. Small nitrogen fertilizer	61,622	583	13,813	24	0	0	112,621	2,165	2,165	91,709	2,203,459	21,513	10,600	1,590	4,533	278	32,162,174
13. Phosphate fertilizer	25,118	254	13,988	94	0	0	1,141	0	0	905,741	307,923	20,037	244	0	0	0	3,869,451
14. Potash fertilizer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. Compound fertilizer	492	1	216	0	0	0	53	0	0	79	2,770	4	0	0	0	0	25,777

Table 3.41: cont'd

The whole nation

Measured unit: ton

Name	Gasoline subtotal	Kerosene subtotal	Diesel subtotal	Liquified petroleum gas	Oil refinery plant dry gas: Subtotal	Oil refinery plant dry gas: Among which: self-supply & use	Natural gas (ten thousand cubic meter)	Coke oven gas (ten thou. cubic meter): Subtotal	Coke oven gas (ten thou. cubic meter): Among which: self-supply & use	Bought outer vapor	Electricity power (ten thousand kWh): Subtotal	Electricity power (ten thousand kWh): Among which: self-supply & use	Other energy resource (ton normal coal): Subtotal	Other energy resource (ton normal coal): Among which: Other coal gas	Other energy resource (ton normal coal): Among which: Other petrol products	Other energy resource (ton normal coal): Among which: Other pyro products	Total
Second	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
16. Chemical pesticide	10,779	174	8,233	287	0	0	0	0	0	1,359,901	148,200	7,924	170	3	0	0	1,348,285
17. Organic chemical	161,734	4,183	32,743	8,863	74,644	74,644	18,698	18,698	15,878	5,292,988	492,571	28,238	1,079,493	1,924	576,436	225,497	9,583,261
18. Among which: organic chemical raw material	18,051	1,027	8,560	8,689	73,574	73,574	7,528	10,549	10,542	4,571,193	343,500	17,972	743,115	151	538,558	21,363	5,743,375
19. Coating and pigment	127,336	1,604	16,531	85	0	0	329	329	0	130,619	29,449	46	7,024	1,528	30	0	789,723
20. Dyestuff	3,793	100	1,486	2	0	0	1,191	1,429	0	126,723	34,292	2,103	13,088	174	0	9,193	645,840
21. Chemical reagent	1,199	33	123	0	0	0	19	223	0	198,387	3,391	0	3,620	0	0	2,667	87,789
22. Catalyst and sort of chemical auxiliary	7,228	1,187	3.609	85	0	0	7,629	5,683	5,334	139,863	46,857	8,658	306,177	0	33,393	192,274	1,742,587
23. Adhesive	280	0	27	0	0	0	0	0	0	11,088	809	1	22	0	0	0	13,212
24. Magnetic record material	134	0	323	0	0	0	0	0	0	448	1,001	28	59	0	0	0	11,447
25. Other organic chemical products	3,733	232	2,084	2	1,070	1,070	0	515	0	114,689	33,472	1,430	6,382	73	4,455	0	569,088
26. Synthesis material	8,860	87	1,818	11,584	1,840	1,840	1,684	1,497	0	2,209,085	208,280	538	23,549	341	5,593	8,187	1,754,821
27. Light sensitive material	936	3	85	0	0	0	0	0	0	378,007	7,307	0	9	0	0	0	109,816
28. Rubber products	57,033	372	4,783	19	0	0	3	0	0	639,691	253,206	197	2,360	343	27	6,867	2,908,884
29. Chemical engineer mechanical	5,696	96	2,446	44	0	0	1,5432	151	0	99,280	18,901	10	646	77	7	0	225,095
30. Others	11,385	11,487	7,912	1,481	35,449	18,158	1,468	135,715	71,220	1,087,201	110,805	931	112,750	11,805	48,185	50,227	5,893,964

Table 3.42: ENERGY CONSUMPTION FOR PRODUCTION OF SELECTED CHEMICALS

		1986	1987	1988	1989	1990
Ammonia						
Large scale						
energy per ton ammonia	MJ	41,168	41,868	41,575	40,110	39,374
Medium scale						
coal	kg/t	1,279	1,315	1,299	12,79	1,293
electricity	kWh/t	1,384	1,409	1,408	1,413	1,393
steam	kg/t	2,730	2,600	2,690	2,550	2,526
energy per ton ammonia	MJ	65,531	66,018	64,828	64,272	63,785
Small scale						
coal	kg/t	1,722	1,851	1,829	1,782	1,676
electricity	kWh/t	1,293	1,445	1,455	1,383	1,333
energy per ton ammonia	MJ	68,216	71,347	70,836	68,622	66,323
Fertilizers, energy and feedstock						
N fertilizer	TCE/t	4.12	3.90	4.14	3.94	3.86
P fertilizer	TCE/t	1.38	1.13	1.13	1.11	0.94
Overall	TCE/t	3.54	3.27	3.42	3.37	3.13
Fertilizers, electricity						
N fertilizer	kWh/t	2,374	2,534	2,549	2,484	2,522
P fertilizer	kWh/t	815	850	776	833	747
Overall	kWh/t	2,070	2,154	2,128	2,158	2,078
Caustic soda						
total energy consumption	10^6 TCE	4.54	1.92	5.31	5.82	6.00
of which, coal	10^6 TCE	1.87	2.03	2.17	2.42	2.41
electricity	GWh	6,613	7,163	7,774	8,422	8,884
AC electricity	kWh/t	2,626	2,619	2,610	2,625	2,650
steam	t/t	5.20	5.19	5.09	5.29	5.08
overall	TCE/t	1.80	1.80	1.78	1.82	1.79
Calcium carbide						
total energy consumption	10^6 TCE	4.95	5.26	4.95	5.66	5.02
of which, electricity	10^9 kWh	77.1	78.3	80.3	89.1	81.0
electricity use	kWh/t	3,585	3,559	3,567	3,621	3,550
total energy use	TCE/t	2.3	2.2	2.2	2.3	2.2
Soda ash						
total energy use	10^6 TCE	1.05	1.16	1.21	1.43	1.94
in ammonia soda process	TCE/t	0.560	0.570	0.544	0.539	0.613
in joint process	TCE/t	0.410	0.410	0.400	0.416	0.391
overall	TCE/t	0.486	0.494	0.475	0.479	0.517

3.211 With respect to the proportion of energy costs in relation to overall manufacturing costs, these are generally high for many subsectors of this industry. For example, energy costs as a percentage of total manufacturing costs for some key products are as follows:

(percent)	Fuels	Elec.	Fuel & elec.	Total energy
N fertilizer			25	70-75
Caustic soda	7.5	17.5	25	
Calcium carbide	8	29	37	
Soda ash			19	
Sulfuric acid			12.5	

Energy Efficiency

3.212 The wide range of processes, plant scale and age within the chemicals sector means that energy efficiencies are extremely variable. However, it is recognized that the energy efficiency in the industry is generally rather low. Most furnaces are small, many are chain grate stokers: the average combustion efficiency of chemical industry furnaces and kilns is estimated at 65 percent. Allowing for an efficiency of steam distribution of say 90 percent (and this may be too high) and of heat utilizing equipment of up to 70 percent, the overall energy utilization is around 30-40 percent.

3.213 Some key process efficiencies are known to be low. For example, the efficiency of gasification for synthetic ammonia production is typically 50-60 percent, and the evaporation stage to produce solid caustic soda say 15-20 percent.

Energy Efficiency Trends

3.214 Greater attention is being paid to energy efficiency and it is estimated that the overall energy consumption per unit of product was reduced by about 5.4 percent annually during the Sixth Five-Year Plan (1981-85) and is now being reduced by about 4 percent per year. The elasticity coefficient for energy use (percent change in energy use divided by percent change in production) from 1981 to 1990 was 0.57.

3.215 Measures taken by the industry in recent years range from improving management to major investments in new equipment and technologies. Greater attention is paid to the recovery of by-product materials or wastes, including better heat recovery. Some examples of measures adopted in the production of ammonia and fertilizers in medium and large plants are as follows:

(a) Recovery of hydrogen from purge gases.
(b) Heat recovery in the synthesis gas reformer.
(c) Use of flash steam in CO_2 recovery systems.
(d) Computer monitoring and control of key process parameters, such as the ratio of hydrogen to nitrogen, combustion systems, purge gas rates, etc.
(e) Upgrading and increasing the size of small gasification units.
(f) Gasification grate improvements and automated coke feeding.
(g) Use of superheated steam in gasification.
(h) Improved automatic control.
(i) Use of heavy oil with carbon slurry for gasification feed.
(j) More efficient CO and CO_2 removal technologies.
(k) Installation of waste heat boilers on medium-scale reformers.
(l) Adoption of improved catalyst.

3.216 Small-scale ammonia plants are typical in the Chinese chemicals industry. About 40 specific measures are being widely enforced to save energy and reduce material waste. Many of these are similar to the measures listed above, and also include various revamp procedures such as improved gas recycling, measures for self-sufficiency in steam, and increased water recycling.

3.217 In phosphorous fertilizer manufacture, emphasis is being placed on modifying furnace types, to waste heat recovery and to better process operation.

3.218 In the manufacture of caustic soda, a variety of energy saving measures are being utilized, such as:

(a) Improved electricity rectification.
(b) Improvements to brine purity.
(c) Replacement of graphite anodes by metal anodes.
(d) Ion exchange techniques.
(e) Adoption of triple effect evaporation.
(f) Increased condensate recovery and heat utilization.
(g) Control of electrolyte concentration.
(h) Recovery of residual heat in hydrogen and chlorine.
(i) Waste heat recovery from HCL synthesis reaction.

3.219 During the early 1980s, the production of calcium carbide was raised and technical improvements to the process were introduced, some of which were imported. These included:

(a) Converting open furnaces to sealed types allowing gas recovery.
(b) Use of hollow electrode technology.
(c) Using waste furnace gas for limestone calcining kilns, with improved gas cleaning methods (estimated saving, 0.17 t coke per t carbide).
(d) Wider use of computer control for reactor optimization.

3.220 Also during the first half of the 1980s, the soda ash industry expanded rapidly and the technical level was raised. Computers are now being used more extensively and process improvements include the use of steam calciners, flash distillation of liquid wastes, larger carbonization towers, and vacuum distillation techniques.

3.221 Although the Chinese output of sulfuric acid is ranked third in the world, most plants are small. Only 40 percent of the production is made in medium or large plants with capacities over 4,000 tpy. However, improvements in energy efficiency are being made, such as:

(a) Recovery of the heat of reaction to reach total heat self-sufficiency, and heat export in some cases.
(b) Generation of electricity from steam produced by high temperature heat recovery.
(c) Improved catalysts.
(d) Adoption of heat pumps.

It is recognized that much medium and low level waste heat is available and could possibly be recovered for useful applications.

Potential for Improvement

3.222 For the manufacture of fertilizers, the potential to improve energy efficiency is good. The average energy consumption of a large-scale ammonia plant in China is about 1.3 TCE compared with perhaps 1.2 TCE in more advanced countries. However, for medium-scale ammonia plants, the figure is 2.5 TCE, for small plants 2.2 TCE. There is estimated to be a potential saving of 0.1 to 0.2 TCE per ton of ammonia production, at least in medium and large-scale plants. This amounts to about 1.3 million TCE savings per year.

3.223 In the making of caustic soda, it is estimated that the difference between Chinese electricity consumption and consumption in advanced countries is about 400 kWh per ton of product (2,500 versus 2,100 kWh/t). Overall energy consumption, including thermal and electrical energy, differs by say 0.2 TCE/t (1.8 TCE/t in China versus 1.5-1.6). Based on present output, this represents a potential saving of around 0.6 million TCE/yr. If the ion exchange technology were to be adopted widely, this potential saving could be doubled.

3.224 Similarly, it is estimated that potential savings for the manufacture of soda ash are of the order of 0.6 million TCE/yr, while savings for the calcium carbide are over 130 million kWh/yr.

3.225 For the sector as a whole, it is expected that the energy used per Y 10,000 output value will decrease from 13.75 in 1990 to 10 in 2000, with savings of around 60 million TCE/yr.

Projected Industry Outputs and Energy Consumption

3.226 According to plans, the chemical industry output is expected to increase by 6.7 percent a year to reach Y 145 billion by 2000 from 77 billion in 1990, itself a doubling of the output in 1980. Chemical product quality will be improved and the pattern of products will change, with a shift towards more downstream processing and more consumer products.

3.227 The anticipated outputs of major products are indicated in Table 3.43, together with forecasted specific energy consumptions. For the chemical industry, it is expected that energy consumption will increase by about 3.7 percent annually. The total energy use by the industry is expected to reach about 125 million TCE in 1995 and 140 million TCE in 2000.

Generic Investment Options

3.228 Three measures were selected for detailed examination as case studies in the chemicals sector, two concerning ammonia production and one relating to the manufacture of caustic soda:

CH1 Renovation of medium-scale coal based ammonia plants.

Most small and medium-scale chemical fertilizer plants in China are based on coal as a raw material and energy source. Many were built in the 1950s and 1960s and use old equipment and outdated process technology. Efforts have continued from the early 1980s to improve their operation by applying a wide range of measures, and some success has been achieved. Major renovations to upgrade equipment and processes are possible, resulting in higher energy efficiency and increased capacities. These include adopting cogeneration systems, the use of steam turbines in place of large electric motors, the use of improved shift reaction catalysts, and improvements to ammonia synthesis towers.

CH2 Waste heat recovery in small coal based ammonia plants.

There are over 1,000 small coal based plants producing ammonia, mostly built in the 1960s and 1970s: these make ammonium bicarbonate and are responsible for over half the annual output of ammonia in China. Although efforts have been made to improve their energy efficiency over the years, equipment and processes are generally outdated. Major renovation of the process is possible, including improvements to synthesis gas generation, gas compression and treatment, and substantial improvements to heat exchanger networks and more effective use of heat.

CH3 New membrane technology for caustic soda electrolysis.

Table 3.43: FORECASTS OF OUTPUT AND SPECIFIC ENERGY CONSUMPTION FOR THE CHEMICALS INDUSTRY

	1990	1995	2000	2010
Output forecasts (million tons per year)				
N fertilizers	14.64	15.70	18.35	20.00
P fertilizers	4.12	5.00	5.50	9.00
K fertilizers	0.05	0.30	0.48	1.00
Total fertilizers	18.81	21.00	24.33	30.00
Caustic soda	3.35	4.00	6.00	7.00
Soda ash	3.79	5.20	6.85	8.00
Sulfuric acid	11.89	14.00	13.00	20.00
Calcium carbide	2.28	2.70	3.00	3.50
Specific energy consumptions (TCE/ton)				
N fertilizers	3.86	3.40	3.26	3.05
P fertilizers	0.94	0.92	0.89	0.87
Average	3.13	2.80	2.65	2.45
Caustic soda	1.79	1.70	1.60	1.45
Soda ash, Solvay process	0.61	0.59	0.55	0.46
Soda ash, ...	0.39	0.38	0.35	0.30
Calcium carbide	2.20	2.14	2.00	1.80
Ammonia -- large scale		1.10	1.07	1.00
Ammonia -- medium scale		1.93	1.79	1.75
Ammonia -- small scale		2.00	1.88	1.80

Electrolysis of brine for caustic soda production consumed about 15 percent of all the electricity used by the chemical industry in 1990. Most Chinese plants use either metal or graphite electrode technology and energy efficiencies are moderate to low. Modern membrane technology can allow important reductions in electricity use and will also allow higher quality caustic soda to be produced which is suitable for export markets.

3.229 Based on actual plant data from enterprises where the above measures have been or will be installed, economic evaluations were carried out with the following results:

	IRR %	Payback, years /a
CH1 Renov. medium plants	19.5	10
CH2 Waste heat recovery	71.4	3
CH3 Membrane technology	29.4	6

/a Payback includes construction time.

3.230 Based on sector characteristics, forecasts of adoption of the measures listed were made for business as usual and accelerated scenarios. These are as follows, referred to annual plant capacity in million tpy ammonia:

	1990	2000	2010
CH1 Renov. Medium-Size Plants (million tpy NH_3)			
BAU not renovated	1.5	1.5	1.5
renovated	0.0	0.0	0.0
Accel. not renovated	1.5	1.2	0.6
renovated	0.0	0.3	0.9
CH2 Waste Heat Recovery, Small Plants (million tpy NH_3			
BAU unmodified	7.5	6.0	0.0
with WHR	0.0	1.5	7.5
Accel. unmodified	7.5	4.5	0.0
with WHR	0.0	3.0	7.5
CH3 Membrane for Caustic Soda (million tpy caustic)			
BAU unchanged technology	3.0	3.0	2.7
with membrane	0.0	0.0	0.3
Accel. unchanged technology	3.0	2.4	1.5
with membrane	0.0	0.6	1.5

3.231 Further details of the assumptions made and the energy and emissions factors used in the calculation are given in Appendix A.

Projected Impacts on Energy and Emissions

3.232 Using the forecasts indicated above, the expected impacts on energy consumption in the chemicals sector are as follows:

	Savings 10^3 TCE/yr by 2000		Savings 10^3 TCE/yr by 2010	
	BAU	Accel.	BAU	Accel.
CH1 Renov. medium plants	0	123.7	0	371.0
CH2 Waste heat recovery	414.1	828.2	2,070.4	2,070.4
CH3 Membrane technology	0	528.7	264.3	1,321.7

Reductions in CO_2 emissions were calculated as follows:

	CO_2 reduction 10^3 TPY by 2000		CO_2 reduction 10^3 TPY by 2010	
	BAU	Accel.	BAU	Accel.
CH1 Renov. medium plants	0	93.3	0	280.0
CH2 Waste heat recovery	270.2	540.4	1,350.9	1,350.9
CH3 Membrane technology	0	352.2	176.1	880.6

Emissions

3.233 The chemical industry is a source of a wide variety of pollutants and waste materials. In 1990, the industry produced about 40 million tpy of solid wastes, of which 14 million tpy were produced from furnaces of all kinds. Gaseous wastes totalled about 700 billion cubic meters and liquid wastes about 6.9 billion cubic meters.

3.234 Solid wastes are very diverse and include unreacted materials, products that fail to meet specification, spent catalysts, ashes discharged from furnaces and from pollution control equipment, and muds from water treatment systems. The quantity of solid waste produced by the industry is substantial—typically, one ton of product is made in conjunction with 1-3 tons of solid waste (and sometimes as much as 12 tons). An indication of the quantities of important waste materials produced each year is given in Table 3.44 together with estimates of the proportion of materials that are used. Table 3.45 provides examples of waste products and their potential utilization.

Table 3.44: UTILIZATION OF WASTE MATERIALS

Type of waste material	Annual production 10^3 t	Amount reused 10^3 t	Percent utilization
Coal ashes and residues	11,200	10,700	95.5
Oil residues	75	59	78.7
Waste from caustic soda	1,300	210	16.2
Residues from FeS ores	7,700	5,800	75.3
Residues from yellow P	340	328	96.5
Industrial kiln slags	795	566	71.2
Waste water treatment sludge	236	210	89.0
Residue from carbide manufact.	1,128	843	74.7
Residue from chromium manufact.	110	45	40.9
Residue from soda ash manufact.	400	43	10.8

3.235 Large quantities of liquid wastes are also made by the chemicals industry, which consumes 13 billion cubic meters of water annually. Of this, about 6.9 billion cubic meters are discharged as liquid pollutants. It has been estimated that, on average, the recycling of water in the chemical industry is 35-40 percent, and the industry discharges about 0.05 tons of waste liquid per Y 10,000 output value. In some enterprises located in areas where water is scarce, water recycling has reached 80 percent, indicating the scope for improvement generally.

3.236 The chemical industry is also responsible for large quantities of waste gas discharges. It is estimated that about 25 million tons of CO^2 and 0.85 million tons of SO2 are emitted each year. Table 3.46 provides information on the quantities produced and extent of utilization of some major gaseous emissions.

3.237 In future, the absolute quantities of solid, liquid and gaseous emissions are expected to increase because the output of the chemical industry is expected to continue to grow at 6 to 7 percent annually. However, with improved energy efficiency and greater concern for pollutant reduction, emissions per unit of production will be decreased.

G. PETROCHEMICALS

Industry Profile and Products

3.238 The petrochemical sector is a major energy consumer, using energy resources both for operating plants and processes and as a raw material for most of the products. Most of the sector is under the overall management of the China Petrochemical

Table 3.45: CHEMICAL INDUSTRY RESIDUES

Chemical industry and its residue	Technology of disposal residue and comprehensive utilization	Chemical industry and its residue	Technology of disposal residue and comprehensive utilization	Chemical industry and its residue	Technology of disposal residue and comprehensive utilization
Inorganic industry		Calcium carbide residual	Technique of road building materials	Sulfuric acid industry	
Chrome residue	Dry-antidotal technique	Phosphate fertilizer industry		Residual of iron pyrite	Producing bricks
	Making for coloring agent of glass	Yellow phosphorous residual from electric furnace	Techniques of making cement		Technique of chloride treatment by high temperature
	Making for Ca-M-P fertilizer	Phosphorous sludge	Technique of producing phosphoric acid by firing		Technique of extractive Au,Ag,Fe by cyanide process
	Calcium-Iron power, etc.	Phosphor gypsum	Technique of producing sulfurate and cement	Waste catalyzer	Recovery V_2O_5 from catalyzer containing vanadium
Phosphorus sludge	Produce phosphoric acid by firing		Technique of making a Serriwater gypsum powder and ball	Industry of organic raw materials and synthetic processed materials	
Yellow phosphorous residue from electric furnace	Produce silicate cement in blending	Nitrogen fertilizer industry		Waste liquor	Recovery pentaerythritol liquor by crystallization process by stages
Cyanogen residue	Disposal technique of hydrolysis oxidation by high temperature	Cinder from gas-making furnace	Technique of making cinder bricks	Distillation waste liquor	Treatment waste formaldehyde liquor by condensation process
Chloro-alkali industry		Cinder from furnace	Technique of making cinder brick		Technique of treatment waste organ-fluorine liquor by burning
Salt sludge contain mercury	Technique of disposal sodium hypochlorite by oxidation process		Technique of making cinder brick	Foul sludge	Technique of burning mixing foul sludge in rotary kiln
	Technique of chlorination and vulcanizing by firing	Waste catalyzer	Technique of producing Zn-Cu compound micro-fertilizer	Dyestuff industry	
Salt sludge non-contain mercury	Technique of producing magnesium oxide with salt sludge		Technique of recovery veclaim platinum family metals	Waste residual containing copper	Recovery copper sulfate from waste residue containing copper
	Technique of settling and filtering process	Sodium carbonate industry		Waste liquor	Recovery the paper agent and waste acid from waste chloride liquor
Calcium carbide residue	Technique of producing cement by CaC residual	Waste liquor of distillation ammonia and waste sale sludge	Technique of producing calcium chloride and remaking sale	Photosensitive material industry	
	Technique of producing bleaching liquor by CaC residual		Technique of producing Ca-M fertilizer	Waste film	Technology of recovery waste film and Ag

Corporation (SINOPEC) and this report covers primarily these activities, which include both oil refining and petrochemical manufacture.

Table 3.46: WASTE GAS PRODUCTION AND UTILIZATION

Type of waste gas	Annual production 10^6 m^3	Amount utilized 10^6 m^3	Percent utilized
Calcium carbide furnace gas	9,840	128	1.3
Coke oven gas	1,500	1,410	94.0
Yellow P furnace gas	3,250	946	29.1
Fertilizer furnace gases	720	346	48.0
Electrolytic hydrogen	40	27	66.8
Benzene plant tail gas	240	29	12.0
Synthetic ammonia plant gases	39,744	28,218	71.0
Carbon black tail gas	3,520	2,288	65.0
Total	58,854	33,391	56.7

3.239 In 1990, the total industrial output of SINOPEC reached Y 44.2 billion. The SINOPEC plants processed 96.9 million tons of oil out of 107.2 million tons processed in China. About 4 million tons of crude oil were imported in 1990. Products included:

Product	Quantity 10^3 t
Gasoline, diesel, luboils	47.21
Ethylene	1.44
Synthetic fibers	0.40
Synthetic rubber	0.23
Ammonia	3.18
Urea	4.96
Organic products	3.21

Although the majority of products were sold domestically, SINOPEC also exported 33 million tons of finished petroleum products and petrochemicals in 1990.

3.240 Crude oil distillation capacity in China is 144 million tpy, of which 124 million is under SINOPEC. This ranks China fourth in the world in terms of distillation capacity, which is now equivalent to about 2.9 million barrels per day. With respect to ethylene production, China is ranked eighth in the world, with 1.96 million tpy capacity of which SINOPEC operates 1.82 million tpy.

3.241 From 1985 to 1990, SINOPEC has invested in technical renovations in about 300 main production units at a cost of Y 8.3 billion for over 900 major projects.

3.242 Data on the facilities and production of SINOPEC are given in Tables 3.47 and 3.48.

Energy Use

3.243 The consumption of energy resources by SINOPEC has reached over 26 million TOE for fuels, power, and feedstock (equivalent to 37 million TCE). Energy consumption per Y 10,000 of output value was 4.84 TOE in 1989, broken down as follows:

	TOE per Y 10,000	Average annual reduction 1983-9 %
Refining	2.46	2.2
Petrochemicals	8.65	3.7
Chem. fibers	1.74	17.9
Fertilizers	22.42	2.0
Whole SINOPEC	4.84	3.6

3.244 The growth in energy use has been quite rapid in recent years due to the commissioning of three large ethylene plants and associated downstream units. This has contributed to the noticeable emphasis on petrochemical and chemical fiber operations:

Year	Fuel/power 10⁶ TOE	%	Feedstock 10⁶ TOE	%	Total 10⁶ TOE	Oil refining	Petrochem & chem fiber	Chem fert.
	Energy consumption					Percent by subsectors		
1983	10.47	71.4	4.19	28.6	14.66	37.3	34.9	27.8
1984	10.63	71.0	4.35	29.0	14.98	34.7	37.8	27.5
1985	11.03	69.2	4.01	30.8	15.94	32.8	38.4	28.3
1986	11.63	70.0	4.98	30.0	16.61	34.2	38.8	27.0
1987	11.76	67.9	5.56	32.1	17.31	34.8	40.5	24.8
1988	14.19	64.9	7.66	35.1	21.85	28.2	53.4	18.3
1989	13.63	61.2	8.65	38.8	22.28	28.8	52.4	18.9
1990	14.97	57.3	11.14	42.7	26.11	25.3	59.7	15.0

Table 3.47: ECONOMIC AND OTHER INDICATORS FOR SINOPEC, 1985-90

	1985	1986	1987	1988	1989	1990
Industrial output value (Y billion)						
1980 constant prices	30.0	32.6	35.4	39.2	41.8	44.1
Current value	33.7	38.7	43.2	50.0	58.8	63.2
Total staff (10^3 persons)	536	567	596	629	651	672
Of which, technical	49	53	59	69	74	78
Managerial	67	73	76	76	81	85
Fixed assets, original value at year end (billion RMB)	24.7	27.8	31.0	42.7	49.9	60.8

3.245 The energy consumption of each subsector may be subdivided further. Tables 3.49 and 3.50 give the position for oil refining. It will be seen that there has been a steady increase in the amount of energy contributed by coke burning in the FCC units, now up to about 23 percent of the total energy supply. This is probably due to greater demand for light products such as gasoline and diesel compared with heavy fuel oil requiring greater levels of cracking in the refining stage.

3.246 For the chemicals operations, the energy consumed in 1990 may be divided as follows:

	Fuel & power	Feedstocks
Petrochemicals, chemical fibers	41%	59%
Chemical fertilizers	35%	65%

For the petrochemicals and fiber production, the fuel and power may be broken down further (data based on 1989 figures):

Energy used for water supply	10.4%
Electricity	17.4
Steam	39.9
Fuel for process heaters	30.2
Miscellaneous	2.1
	100.0

Energy Efficiency and Trends

3.247 Efforts to improve energy efficiency have been maintained for several years. The results are shown for refining and petrochemical activities in terms of energy consumption per Y 10,000 in Table 3.51 and as kgOE per ton of crude processed for the refining industry in Table 3.52. Details of energy consumption improvements for a selection of major refining processes are given in Table 3.53 and for selected chemical processes in Table 3.54. In all processes, energy consumptions have been reduced steadily: for refining processes, the rate ranges from 1 to 6 percent per year, and for chemical processes from about 3 to 11 percent per year. For nitrogen fertilizer production, improvements have been made but at a slower rate—well below 1 percent per year, as shown in Table 3.55.

3.248 Figures for the lowest energy consumptions for selected processing operations are reported in Table 3.56 and compared with current levels of energy use, as reported in previous tables, in Table 3.57. Although good results have been achieved in almost all areas, there remain significant differences between the energy efficiency of similar processes in China and overseas.

3.249 The improvements seen in the data for energy use in a wide range of processing operations have been achieved through technical revamping of units, replacing small old units by larger new units, and by close attention to management of the plants. Investments in energy conservation projects reached Y 890 million in the six years up to 1990:

Table 3.48: OUTPUT OF MAIN PRODUCTS OF SINOPEC, 1985-1990

10^6 tons	1985	1986	1987	1988	1989	1990
Crude processed						
SINOPEC	79.04	85.65	90.00	93.28	96.23	96.96
whole industry	84.50	91.58	97.18	101.61	105.28	107.23
% of total	93.5	93.5	92.6	91.8	91.4	90.4
Total oil products						
SINOPEC	37.72	41.86	43.43	44.88	47.03	47.21
whole industry	39.88	44.24	46.45	48.43	51.12	52.08
% of total	94.5	94.6	93.5	92.7	92.0	90.7
including						
Gasoline						
SINOPEC	13.46	15.39	15.83	17.12	18.39	18.95
whole industry	14.38	16.47	17.12	18.66	20.21	31.16
% of total	93.6	93.5	92.4	91.7	91.0	89.5
Kerosine						
SINOPEC	3.94	4.05	4.07	3.73	3.85	3.75
whole industry	4.03	4.14	4.16	3.81	3.93	3.85
% of total	97.8	97.9	97.9	97.8	97.8	97.6
Diesel fuel						
SINOPEC	18.90	20.92	21.94	22.39	23.15	22.07
whole industry	19.89	21.99	23.38	24.13	25.17	25.37
% of total	95.0	95.1	93.8	92.8	91.9	90.5
Luboil						
SINOPEC	1.43	1.50	1.60	1.64	1.64	1.54
whole industry	1.58	1.64	1.79	1.83	1.81	1.69
% of total	89.5	91.4	89.3	89.3	90.4	91.0
Ethylene						
SINOPEC	0.55	0.59	0.82	1.11	1.27	1.44
whole industry	0.65	0.70	0.94	1.23	1.40	1.57
% of total	84.5	84.4	87.3	90.2	91.1	91.6
Plastics						
SINOPEC	0.50	0.56	0.73	1.03	1.20	1.36
whole industry	1.23	1.32	1.53	1.91	2.06	2.29
% of total	40.4	42.1	47.7	53.8	58.5	59.5
Synthetic rubber						
SINOPEC	0.13	0.13	0.15	0.19	0.22	0.24
whole industry	0.18	0.19	0.22	0.26	0.29	0.32
% of total	71.0	68.8	66.7	74.9	75.6	75.0
Synthetic fibers						
SINOPEC	0.31	0.31	0.33	0.35	0.38	0.40
whole industry	0.77	0.88	0.98	1.13	1.28	1.43
% of total	40.0	37.7	33.5	30.9	29.7	28.1
including monomers						
SINOPEC	0.49	0.51	0.53	0.59	0.61	0.78
whole industry	0.49	0.52	0.53	0.60	0.62	0.80
% of total	98.7	97.7	98.7	98.5	98.1	98.9
and polymers						
SINOPEC	0.45	0.46	0.48	0.49	0.50	0.50
whole industry	0.61	0.61	0.78	0.90	0.96	0.88
% of total	73.6	75.5	61.8	54.6	51.5	56.8

Table 3.49: BREAKDOWN OF REFINERY FUEL AND POWER BY SOURCE

Percentages	Fresh water	Elect.	Steam	Heater fuel	FCC coke
1983	2.49	13.85	33.18	35.44	15.04
1984	2.40	14.31	31.57	36.45	15.27
1985	2.58	14.05	32.32	34.26	15.80
1986	2.60	15.54	28.75	35.53	17.58
1987	2.64	15.09	28.48	35.99	17.80
1988	2.54	15.80	28.39	33.36	19.91
1989	2.59	15.71	28.09	31.52	22.09
1990	2.76	16.04	28.00	30.68	22.52

Table 3.50: ALLOCATION OF REFINERY ENERGY CONSUMPTION

(Percent)	Units	Storage & handling	Waste water treatment	Domestic uses	Heat loss	Power loss
1983	84.5	7.2	1.3	4.7	1.8	0.6
1984	84.4	7.5	1.3	4.5	1.8	0.6
1986	84.0	8.0	1.4	4.3	1.8	0.5
1987	84.2	8.0	1.2	4.3	1.9	0.5
1988	84.6	7.4	1.1	4.4	2.0	0.5
1989	85.3	7.4	0.9	4.1	1.8	0.5
1990	85.3	7.4	1.0	4.3	1.8	0.5

	1985	1986	1987	1988	1989	1990	Total
Y Million	112.3	144.2	193.6	195.5	115.1	129.0	889.7

3.250 The results of these energy conservation investments are estimated to have been savings of 0.9 million tons oil equivalent. It is estimated that the investment needed to save 1 ton oil equivalent is about Y 990 and the payback for the investment is on average 1.1 years.

Table 3.51: ENERGY CONSUMPTION PER Y 10,000 OUTPUT VALUE

Tons oil equivalent per Y 10,000

	1984	1985	1986	1987	1988	1989	%/yr
SINOPEC	5.44	5.28	5.12	4.93	4.80	4.84	-3.6
Refining	2.70	2.59	2.52	2.51	2.37	2.46	-2.2
Petrochemicals	10.03	9.91	8.40	8.48	8.74	8.65	-3.7
Chemical fibers	4.14	3.56	2.01	1.93	1.84	1.74	-17.9
Chem. fertiliser	24.75	23.85	21.78	21.75	-	22.42	-2.0

Note: The energy consumption of three major new ethylene plants not included.

Table 3.52: ENERGY CONSUMPTION FOR OIL REFINING

	1984	1985	1986	1987	1988	1989	1990	%/yr
Overall refinery energy use kg OE/ton crude	71.2	70.1	70.4	68.0	69.4	71.0	72.7	-0.02
Refinery processing kg OE/t crude	66.8	65.8	66.5	64.6	66.5	69.2	70.2	-0.05

3.251 Some specific measures that have been taken to improve energy efficiency are as follows:

(a) Revamping refinery processing units by improving process efficiency and using higher efficiency equipment.

(b) Increasing the recovery of energy, e.g., using multi-effect evaporators at Maoming to reduce energy consumption 34 percent; low temperature waste heat recovery; recovery of heat from stack gases.

(c) Application of computers for improving management of facilities, optimizing energy use and improving product yields, e.g., computer control on 26 out of 39 FCC units and on 16 out of 64 crude distillation units; microprocessor control on 140 large process heaters raising combustion efficiency by 2-5 percent; refinery optimization at the Jinxi Complex reducing overall energy consumption by 3 percent; on-line control systems at 6 major fertilizer plants.

Table 3.53: ENERGY CONSUMPTION OF REFINERY PROCESS UNITS

kg OE/t feed	1984	1985	1986	1987	1988	1989	1990	%/yr
Atmospheric and vacuum dist.	14.6	13.6	13.0	13.4	13.2	12.3	12.3	-2.6
FCC	78.4	74.6	73.0	72.6	75.4	70.4	71.5	-1.0
Cat. reforming	159.9	160.4	161.4	153.6	146.7	147.2	131.0	-2.5
Thermal cracking	39.8	40.0	38.5	34.5	34.3	33.2	33.2	-3.9
Delayed coking	37.2	37.6	34.5	30.0	30.1	28.1	28.3	-5.2
Propane deasph.	58.6	54.3	50.5	45.3	44.2	40.9	39.2	-6.0
Phenol refining	60.1	56.2	55.7	48.4	46.9	48.1	46.4	-3.7
Furfural ref.	48.8	43.4	39.8	38.6	36.0	33.4	31.6	-4.4
Acetone/benzene dewaxing	98.6	92.3	75.3	72.8	67.9	65.3	66.0	-5.5

Table 3.54: ENERGY CONSUMPTION FOR CHEMICAL PRODUCTS AND FIBERS

kg OE/ton	1984	1985	1986	1987	1988	1989	1990	%/yr
Ethylene	1,354	1,252	-	1,222	1,240	1,225	1,121	-3.3
Polypropylene	626	618	521	453	473	423	422	-6.4
Butyl rubber	1,036	1,074	808	801	773	744	740	-5.5
Phenol	2,151	2,062	1,580	1,227	1,124	1,054	1,086	-10.8
Ethylene oxide	1,141	1,079	1,015	1,064	908	752	674	-8.4
Acrylonitrile	1,040	854	804	771	-	770	647	-7.6
Poly acrylonit.	2,700	2,670	2,571	-	2,450	2,445	2,401	-2.1
Terylene staple	792	608	596	401	380	382	366	-12.1
Vinylon	1,692	1,622	1,546	1,551	1,511	1,425	1,402	-3.1
Nylon staple	1,050	988	827	806	803	725	-	-7.1

(d) Process improvement for FCC units and the increased deeper processing of heavier crudes.

(e) Introduction of new ethylene plants and renovation of older facilities, especially pyrolysis furnaces, to increase ethylene yields from poorer feedstocks.

Table 3.55: ENERGY CONSUMPTION FOR NITROGEN FERTILIZER PRODUCTION
kg OE/ton

1983	1984	1985	1986	1987	1988	1989	1990	%/yr
1,733	1,670	1,663	1,699	1,652	1,666	1,635	1,650	-0.06

Note: 1990 data includes high energy consuming Ningxia Chemical Works which entered operation.

Potential for Improvement

3.252 The gaps between average energy consumption and the best recorded performance for a range of products and processes are shown in Table 3.57, indicating the possibilities for further improvement. For refinery processing, the difference is about 20 percent and for many chemical processes 30 percent, and for fertilizer production about 11 percent. Renovation measures need to be checked for economic viability but experience in many plants suggests that energy conservation is usually an attractive investment. It is therefore expected that energy efficiency will continue to rise by adopting many of the same technologies as applied already, such as those listed above.

3.253 In particular, efforts should continue to close down small and primitive crude oil refining facilities. For example, there are 56 small refineries with annual throughput under 500,000 tons, scattered through 14 provinces and cities: their total distillation capacity is 8.265 million tpy. Of these small refineries, 16 are run by oilfield administrations (3.99 million tpy) and 40 are run by local governments (4.275 million tpy). Tests at 12 of the better small refineries indicate that energy consumption runs about 60 percent higher than typical large refineries. In addition, a number of primitive processing units installed in the 1930s remain in service in spite of central government efforts to have them banned. About 3,000 such units in 1986 were reduced to 400 in 1990. Most of these use simple and obsolete equipment and yield perhaps 20 percent of their feed as petroleum products, often below specification. Excessive energy consumption is estimated to be 1 million tpy.

3.254 With respect to SINOPEC refineries, there are 34 in operation with an average crude distillation capacity of 3.65 million tpy which is about half the average of oil refineries in developed countries. The actual amount of crude processed in Chinese refineries in 1990 was under 3 million tpy (see Table 3.59). Production scale should therefore be increased to achieve higher energy efficiencies and better use of capital investments.

3.255 Another area where savings may be made is in the effective use of wellhead gas. About 13 percent of this is typically flared off and wasted. For example, the natural

Table 3.56: LOWEST REPORTED ENERGY CONSUMPTION VALUES

Processing unit	kgOE/t	Year	Location
Refinery units			
Atmos/Vacuum distill.	10.6	1987	Maoming Petrochemical Co.
FCC	59.0	1990	Refinery of Jilin Chem Co.
Thermal cracking	49.2	1989	Maoming P.C.
Delayed coking	20.4	1990	Dushanzi Refinery
Cat. reforming	132.2	1989	Shenli Refinery
Acetone/benzene dewax.	57.5	1988	Dushanzi Refinery
Phenol refining	43.8	1990	Shanghai Ref, Gaoqiao P.C.
Furfural refining	27.1	1989	Maoming P.C.
Propane deasphalting	31.2	1990	Maoming P.C.
Petrochemicals			
Ethylene	854.3	1989	Qianjin Plant, Yanshan PC
HDPE	306.4	1989	Qianjin Plant, Yanshan PC
LDPE	280.9	1989	Chem Plant 3, Liaoyang PC
Phenol	874.4	1989	Xiangyang Plant, Yan.PC
Ethylene oxide	576.8	1989	Chem Plant 2, Jinling PC
Butyl rubber	711.3	1990	Shengli Plant, Yan.PC
Chemical fibers			
Polyester	159.0	1990	Terylene Factory 2,Shanghai GPW
Acrylonitrile	472.9	1990	Chem plant 2, Daqing GPW
Acrylic fiber	2,282.7	1990	Acrylic Fiber Plt. Shanghai GPW
Terylene staple	291.3	1990	Terylene Factory, Tianjin PC
Vinylon staple	1,319.2	1990	Chem Fiber Plt. Sichuan Vinylon
Chemical fertilisers			
Large scale N fert.	1,491	1985	Fert Pt 2, Qilu Petrochem Co.
Ammonia consumed for urea prod'tion kg/t	582	1984	Fert Pt 2, Qilu Petrochem Co.
Ammonia synthesis			
gas feedstock	865	1986	Fert Pt 2, Qilu Petrochem Co.
naphtha feed.	881	1990	Fert Pt Jinling PC
residual oil feed.	1,013	1987	Fert Plant, Zhenhai GPW

gas recovered and sold by pipeline from the Xinjiang oilfield is only 83 percent of total output (dropping to about 68 percent during the summer). The Daqing oilfield produces 2.5 billion m^3 annually and yet sells only 1 billion m^3. The Zhongyuan oilfield blew off and flared the equivalent of 1 million tons of crude oil from 1979 to 1985. The Anzhai oilfield produces 500,000 tpy of crude and 36 million m^3 of associated gas is unrecovered.

Table 3.57: SUMMARY OF CURRENT AND BEST ENERGY CONSUMPTIONS

kg OE/t	Average 1990	Best reported	Difference %
Refinery units			
Atm/vac distillation	12.8	10.6	21.3
FCC	71.5	59.0	21.3
Cat reforming	131.0	132.2	–
Thermal cracking	33.2	19.2	73.3
Delayed coking	28.3	20.4	38.9
Acet/benz. dewaxing	66.0	57.5	14.8
Phenol refining	46.4	43.8	6.0
Furfural refining	31.6	27.1	16.7
Propane deashalt.	39.2	31.5	24.5
Chemicals			
Ethylene	1,121	854.3	31.2
Butyl rubber	740	711.3	4.0
Phenol	1,086	874.4	24.2
Propylene oxide	674	576.8	16.9
Acrylonitrile	647	472.9	36.8
Acrylic fiber	2,401	2,282.7	5.2
Terylene staple	366	291.3	25.6
Vinylon	1,402	1,319.2	6.3
Major fertilisers	1,659	1,491.0	11.3

A rough estimate suggests that about 80,000 tons of propane and ethane are lost every year from oil and gasfield in China. Additional recovery of light hydrocarbons could make a significant contribution to petrochemical feedstocks.

3.256 Improving product quality will also be a factor in the future. For example, the main part of the gasoline pool is 70 MON. Improved efficiency of gasoline driven vehicles can be achieved using higher octane fuels and it is planned to increase the proportion of FCC gasoline in gasoline blends. Diesel fuel often cannot meet the 45 cetane number specification: some refineries can barely reach 40. Efforts are therefore needed to increase cetane numbers, improve fuel stability and lower the pour point.

3.257 A program to reduce product losses by greater use of floating roof storage tanks for light products is needed. Potential savings have been estimated at 4.5 million tpy of products for an investment of Y 1.12 billion, equivalent to Y 250 per annual ton saved.

3.258 Finally, efforts will be made to improve the level of energy conservation management, both in a technical sense and by applying management principles. Some technical examples are:

Table 3.58: FORECASTS FOR PRODUCT OUTPUTS

	1990		1995		2000	
	10^6 tons	%	10^6 tons	%	10^6 tons	%
Crude oil processed	107.23		150		200	
Total products	96.88	100	125.05	100	157.92	100
Gasoline	21.16	21.8	29.14	23.3	37.13	23.5
Kerosene	3.85	4.0	6.18	4.9	7.65	3.8
Light oil for chemicals	7.85	8.1	16.58	13.3	21.64	13.7
Diesel oil	25.37	26.2	38.88	30.7	54.25	34.4
Luboils	1.69	1.7	2.99	2.4	3.92	2.5
Resid fuel oil	32.17	33.2	25.53	20.4	25.01	15.8
Bitumen	2.73	2.8	4.23	3.4	5.83	3.7
Pet. coke	1.36	1.4	2.07	1.7	2.44	1.5
Wax	0.69	0.7	-	-	-	-
Ethylene	1.44		2.30		3.45	
Fuel and power for petrochemical industry	14.97		18.7		23.2	

(a) Computer optimization techniques for operating units.

(b) Pinch point (or process integration) techniques for optimizing heat exchange systems.

(c) Improved combustion efficiency of fired heaters.

(d) Improved trays and packing in fractionating towers.

(e) Higher efficiency electric motors.

(f) Improved process technologies (e.g., better catalysts in FC and naphtha reforming units, different solvents for luboil refining, and by equipment and process flow modifications of many kinds).

(g) Waste heat recovery and utilization of recovered energy.

Table 3.59: CRUDE OIL PROCESSED IN MAJOR REFINERIES

		10^6 tons, 1990
1	Yanshan Petrochemical Co.	6.54
2	Tianjin Petrochemical Co.	2.97
3	Fushun Petrochemical Co. (3 refineries)	8.01
4	Jinzhou Petrochemical Co.	2.45
5	Dalian Petrochemical Co.	4.76
6	Liaoyang Petrochemical Fiber Co.	2.69
7	Gaoqiao Petrochemical Co.	4.58
8	Jinling Petrochemical Co.	5.32
9	Yangzi Petrochemical Co.	2.30
10	Baling Petrochemical Co.	3.20
11	Maoming Petrochemical Co.	5.76
12	Lanzhou Chemical Industry Co.	0.63
13	Daqing General Petrochemical Works	5.32
14	Shanghai General Petrochemical Works	3.39
15	Lanzhou Petroleum Processing and Chemical Complex	2.76
16	Jinxi Petroleum Processing and Chemical Complex	8.80
17	Zhenhai General Petrochemical Works	2.78
18	Anqing General Petrochemical Works	2.57
19	Guangzhou General Petrochemical Works	3.05
20	Urumqi General Petrochemical Works	1.71
21	Shijiazhuang Refinery	1.38
22	Cangzhou Refinery	0.77
23	Qiangguo Refinery	0.99
24	Harbin Refinery	0.84
25	Linyuan Refinery	1.36
26	Jiujiang General Petrochemical Works	1.55
27	Jinan Refinery	1.36
28	Louyang General Petrochemical Works	1.57
29	Wuhan Petrochemical Works	2.02
30	Jingmen General Petrochemical Works	2.80
31	Dushanzi Refinery	1.84
32	Qilu Petrochemical Co.	6.72
	Total	102.7 million tons

Projected Industry Outputs and Energy Consumption

3.259 Forecasts of growth in crude oil refining and trends in the output of selected refinery products are summarized in Table 3.58. Table 3.59 presents forecasts of ethylene production and overall fuel and power for the petrochemical sector.

3.260 The changes in product mix in the future will influence refinery energy consumption because of the need to convert heavy oil fractions into light oils, partly for use directly as fuels and partly to increase the production of petrochemicals. There is likely to be a significant increase in the use of diesel as a fuel for transport at the expense of gasoline. At the same time, this increase may be offset by efforts to reduce the use of agricultural tractors for rural transport and to reduce the amount of diesel oil used for power generation in TVEs (about 3 million tons will be used in 1995).

Emissions

3.261 The petrochemical industry is a major energy consumer and also uses large volumes of water for process applications and cooling. Each year, the 30 large-scale petrochemical complexes discharge 760 million tons of waste water and 4.7 million tons of solid wastes. The main achievements of the industry in the period from 1986 to 1990 are as follows:

(a) Waste water discharges have been reduced 3 percent and the amount of these meeting environmental standards has risen by 18.6 percent compared with 1985 (to reach a total of 84 percent of discharges).

(b) Total COD discharged in 1990 was reduced by 24.9 percent compared with 1985.

(c) Utilization of combustible gases reached 94 percent, an increase of 4 percent over 1985.

(d) The proportion of toxic gases meeting emission standards reached over 90 percent.

(e) The use of waste solid residues increased by 35 percent to reach a total of 80 percent.

(f) The proportion of enterprises complying with noise emission standards reached over 95 percent.

(g) Energy conservation contributed to a reduction in the quantity of fuel used of 2.25 million tons oil equivalent and a corresponding reduction in CO_2 discharges of 7 million tons in the five-year period.

3.262 Currently the main objectives is to ensure that facilities meet environmental standards. This will require effective management of existing facilities and proper use of existing equipment, as well as modernization of facilities to control pollution sources. New techniques of environmental control need to be developed and disseminated. The main quantitative targets are:

Item	Target
Waste water disposal meeting emission standards	> 85%
COD discharges per 10,000 RMB output value	< 18 kg
Utilization of combustible gases	> 95%
Toxic gas emissions complying with standards	> 95%
Utilization of solid wastes	> 90%
Compliance with noise standards at the boundary	> 95%

H. EQUIPMENT

Introduction to the Equipment Supply Industry

3.263 The machinery and electronic industries in China are large and complex, and play a key role in the national economy by providing a very wide range of equipment to the manufacturing industries, to agricultural enterprises, to the transport sector and indeed to all other energy consuming sectors. The activities of the industry include production of machine tools, electrical machines and motors, construction machinery, scientific and technical instruments, agricultural machinery, automobiles and trucks, ships, radios and televisions, computers, and all types of mechanical and electrical components and spare parts.

3.264 In 1990, the machinery and electronic industries consisted of 104,800 enterprises (excluding township and village enterprises) with 20.62 million employees. Total industrial output was Y 376.5 billion, about one quarter of Chinese industrial output.

3.265 The energy consumption of the mechanical and electronic industries themselves is not particularly large: it is about 1.6 percent of national energy consumption, including 16.52 million TCE of coal. Overall energy consumption was 1.013 TCE per Y 10,000 in 1990, reducing to 0.893 in 1991. Electricity use dropped from 960.2 kWh per Y 10,000 in 1980 to 800.1 in 1991.

3.266 However, the mechanical and electronic industries have a very important influence on Chinese energy consumption in terms of the type of equipment manufactured for the market and its performance (e.g., energy consumption, efficiency, service life, maintenance needs, capital and operating costs). In some cases, the domestic market can purchase modern equipment with good performance: for other items, the Chinese equipment lags behind similar items available in western countries in terms of energy efficiency and other technical features.

3.267 Because of the key role of equipment used by energy consumers in determining their energy consumption, a review of the mechanical and electronic industries was made to determine the status of key products manufactured and to document the efforts being made to improve their quality and energy efficiency. The main products included electric motors, fans and pumps, compressors, industrial furnaces, steam traps and instruments. A separate study of boiler availability and performance was also made.

Electric Motors

3.268 An indication of the scope of the electro-mechanical manufacturing industry is given by the production data presented in Table 3.60. Seven major items of equipment represent over half the national electricity consumption. Motors are the single most important electro-mechanical product, with applications throughout China in all sectors of the economy.

3.269 There are 1,180 motor factories with 58 key enterprises and 640 others under the Ministry, 408 county level factories and 74 others classified as TVEs. It has been estimated that there are now 152 major series of motors and more than 4,000 specifications of motors in China, with the present inventory representing 330 million kW installed load. The annual output of motors in the size range 0.55 to 200 kW is equivalent to 34 million kW: a breakdown by motor size is given in Table 3.61. Over 60 percent of electricity generated in China is used in motors, with motor losses totalling about 5 percent of national demand.

3.270 The main motor series are as follows:

(a) Y series induction motors—available in sizes from 0.55 to 200 kW, these are the most common type of motor and they supersede the widely used J series. Their efficiency on average is 0.4 percent higher than the J series motors replaced. The annual output volume is equivalent to 20 million kW.

(b) YCT series variable speed motors—available in sizes from 0.55 to 90 kW, these motors use an electromagnetic slipping clutch system to change speed. Ten plants provide an annual output of about 450,000 kW.

(c) YD pole changing multi-speed motors—these are modified Y series motors with speeds adjustable in steps depending on the connections for the windings.

(d) YX series high efficiency motors—available in sizes from 1.5 to 90 kW, motor efficiencies are 3 percent higher than the standard Y series motors. Annual output remains low at about 10,000 kW.

3.271 A comparison of motor efficiencies is shown in Table 3.62, showing the improvement of the Y series over the previous J series but also showing that efficiencies lag behind the developed countries.

Table 3.60: MAJOR ELECTRICITY CONSUMING ELECTROMECHNICAL PRODUCTS

Item	Total in China	Main manufact.	Approx. varieties	Annual output	Annual electricity consumption 10^9 kWh	Percent of national electric. generated %	Total output value 10^9 Y	Forecast of output increase pct/year	Total employment 10^3
Small and medium-size elec. motors	0.35×10^9 kW	300	557	45×10^6 kW	32.5	5	6.0	18	200
Blowers and fans, inc. motors	5×10^6 units	300	2,500	0.2×10^6 units	65	10	1.0	16	50
Water pumps	20×10^6 units	923	1,282	4.2×10^6 units	130	20	2.0	17	70
Air compressors	1×10^6 units	161	303	45×10^3 units	58.5	9	1.44	15	60
Power transformers	0.8×10^9 kVA	200	1,155	87×10^6 kW	13	2	3.0	17	90
Electric furnaces	0.7×10^6 units	60	76	$0.6\ 10^6$ kW	32.5	5	0.27	13	13
Electric welders	1×10^6 units	120	83	0.1×10^6 units	3.25	0.5	0.38	14	20
Total					330	51.5			

Table 3.61: Size Distribution of Annual Motor Output

Rate power kW	Annual output 10^3 kW	Rated power kW	Annual output 10^3 kW
0.55	55	22.0	2,500
0.75	75	30.0	2,300
1.1	150	37.0	2,000
1.5	600	45.0	1,900
2.2	800	55.0	1,800
3.0	1,000	75.0	1,500
4.0	1,400	90.0	1,000
5.5	2,000	100.0	1,000
7.5	2,500	110.0	900
11.0	3,000	132.0	800
15.0	3,000	160.0	700
18.5	2,800	200.0	400

Table 3.62: Comparison of Motor Efficiencies

Power kW	China Y series	YX series	JO2 ser.	USA MAC	USA XE	France M2E
1.5	79			81.5-84.0		
5.5	88.5	89.5-90.2	86	88.5-90.2	88.5-90.2	
7.5	87	90.3-90.7	87	88.5-90.2	88.5-90.2	
22	91.5	93.0-93.5	89.5	91.7-93.0	91.7-93.0	92.5
55	92.6	94.2-94.8	91.5	93.0-94.1	94.1-95.0	94.4
75	92.7	94.6-95.0	92	94.1-95.0	94.1-95.0	95.0
90	93.5	94.8-95.2		94.1-95.0	94.1-95.0	95.4

3.272 According to available statistics, the annual repair rate of small motors is about 3-5 percent of the population or about 10 million kW. Most repairs involve stator rewinding. The largest motors are repaired in motor manufacturing plants or in large enterprises but smaller motors are repaired in factories or in repair shops. It is believed there are 100 small repair firms around the country, often with very basic equipment and lacking strict technical supervision. Better control of motor rewinding could contribute to maintaining higher motor efficiencies and thus saving energy.

3.273 Another means of saving energy in many applications is the use of variable or multi speed motors. The most common equipment in China is the electromagnetic clutch or the pole changing motor. Unlike many developed countries, there is relatively little use of variable frequency control systems. These devices lead to much greater energy savings but their cost is higher, as Table 3.63 shows. There is a good potential for saving energy, both by greater use of variable frequency equipment and by a greater adoption of variable speed controls in general.

Table 3.63: COMPARISON OF METHODS FOR SPEED ADJUSTMENT

	YCT electromagnetic motors	YD pole changing motor	Variable frequency device
Principle	Change slip	Change pole number	Change frequency
Application	For stepless speed adjusting	Stepped speed adjusting	Stepless speed adjusting
Maintenance	Easy	Easy	High technical requirement
Reliability	High	High	Can vary
Interference with power supply	No	No	Can interfere
Cost	Y 300/kW	Y 200/kW	Y 1,000/kW
Power factor	High	Fairly high	High
Energy saving	About 20%	About 20%	About 30%
Forecast demand (10^3 kWh)			
1993	400	400	180
2000	2,800	2,650	350
Number of manufacturers	> 20	> 30	> 10

3.274 Finally, it is worth noting that the replacement of J series motors by Y series has already resulted in electricity savings. However, even though the manufacture of J series motors is restricted, it is known that some enterprises still produce them. The J motors are cheaper and are often selected for rural enterprises. Stricter enforcement of regulations restricting the use of old and inefficient J motors could lead to useful savings in electricity.

Fans

3.275 The total number of fans and blowers of all types is around 5 million, consuming about 10 percent of national electricity production (about 65 billion kWh per year). About 400,000 new fans are made annually. It is estimated that about one quarter of these new fans are energy efficient new designs.

3.276 There are over 300 firms making fans, most of them being TVEs. About one third can be considered large companies with good capabilities. There are 85 firms which are members of the Fan Institute of the China General Machinery Corporation and these are widely dispersed throughout the country (Table 3.64). For the whole fan industry, employment was 51,390 in 1990, including 4,207 technicians and 7,209 management staff.

3.277 The industry may be divided into 7 basic groups of products—centrifugal compressors, axial flow compressors, centrifugal blowers, Roots blowers, vane type blowers, and centrifugal and axial flow ventilators. Data on the annual production levels are given in Table 3.65. Overall, there are about 2,500 different products.

3.278 With respect to technological level, it is judged that the large centrifugal and axial flow compressors have reached the international level of the mid-1980s, while low pressure axial flow fans are at the level of the late 1970s. Many fan manufacturers are only just beginning to utilize modern design techniques such as CAD/CAM. For some of the largest fan and blower applications, imported equipment has to be used. The medium and smaller companies lack modern machine tools with fully computerized operation.

3.279 In spite of the backward technology possessed by some firms, efforts are being made to improve fan and blower efficiencies and to upgrade the quality of the products. Several agreements have been made to import more recent technology for selected types of fans and further technology transfer arrangements are planned. It was estimated that adoption of newer designs for over 45,000 equipment sets saved 414 million kWh in 1989. This is under 1 percent of the energy consumed in fans and blowers and therefore there remains a very large potential for energy saving.

3.280 Some difficulties exist, however: for example, many users are unwilling to adapt equipment foundations to install more recent and more efficient machinery. There is also the problem of low efficiency designs being cheaper and easier to make, allowing small firms to sell products with outdated technologies when users fail to make proper life-cycle cost comparisons.

Table 3.64: MAJOR FAN MANUFACTURERS
1990

Name of Company	Employees	Fixed assets (Y 10,000)	Area m²	Production equipment (unit)
Northeast Area				
Shenyang Blower Works	4,161	19,152	300,382	374
No. 1 Branch of Shenyang Blower Works	707	782.1	50,430	92
Shenyang Ventilator Co.	1,043	1,640	113,600	176
Shenyang People Ventilator Co.	917	1,002	51,000	107
Shenyang Cold warm Ventilator Co.	948	1,117.6	38,754	66
Anshan Ventilator Co.	711	627.7	28,265	88
Yingkou Ventilator Co.	252	162	22,500	44
Dalian Ventilator Co.	350	1,989.5	11,640	47
Jingzhou Ventilator Co.	267	267,3	12,762	74
Jilin Blower Co.	669	820.3	40,300	90
Siping Blower Co.	891	1,174.2	115,416	69
Siping Ventilator Co.	453	139	5,120	39
Harbin Ventilator Co.	510	144.5	8,772	56
Harbin Blower Auxiliary Co.	327	82.8	6,872	39
Jinausi Blower Co.	730	693.5	64,498	120
Zhaodong Ventilator Co.	310	203.1	90,628	45
North China and Northwest China Area				
Shanxi Blower Co.	3,337	7,551.2	444,440	277
Shanxi Lishan Ventilator Co.	340	171.1	13,332	38
Xian Ventilator Co.	362	220.5	16,370	46
Xian Chaoyang Ventilator Co.	161	65.6	7,693	28
Beijing Blower Co.	1,749	1,195.2	51,203	136
Beijing Ventilator No. 2 Co.	509	1,388.4	32,439	68
Tianjin Blower Co.	706	1,081.1	29,363	116
Tianjin Ventilator Co.	501	331	17,233	72
Tianjin Warm Ventilator Co.	423	448	10,893	39
Shijiazhuang Ventilator Co.	273	778.8	21,800	108
Baoding Ventilator Co.	627	1,056.4	68,040	84
Xuanhua Ventilator Co.	224	197.8	36,377	33
Yuanping Blower Co.	512	527.3	114,116	88
Huhhot Ventilator Co.	180	200.5	18,584	32
Bactou Ventilator Co.	342	259	63,480	41
Jinyuan Ventilator Co.	153	250.1	32,253	50
Yinchuan Ventilator Co.	316	1,037	454,741	122
Xinjian 7.1 Ventilator Co.	322	252.4	14,848	73

Table 3.64: cont'd

Name of Company	Employees	Fixed assets (Y 10,000)	Area m²	Production equipment (unit)
East China Area				
Shanghai Blower Co.	2,040	4,648.3	121,242	307
Shanghai PengJiang Machinery Co.	152	76.5	2,600	27
Shanghai Great Wall Blower Co.	632	213	8,762	64
Nanjing Blower Co.	533	272.2	29,119	77
Yixing Blower Co.	273	155.2	14,343	32
Changshu Blower Co.	516	675.6	46,800	84
Yangzhou general Ventilator Co.	178	143.9	9,027	27
Nantong Ventilator Co.	681	804.3	36,562	90
Ningbo Ventilator Co.	447	746	43.23	88
Yuyao Ventiator Co.	125	148.2	9,045	31
Zhejiang Shanlu Ventilator Co.	516	859	48,000	90
Fujiang Blower Co.	327	334.5	50,020	96
Jinan Ventilator Co.	847	1,015.7	41,850	119
State-owned Jinan Ventiator Co.	182	194	8,800	45
Jinan No. 2 Ventilator Co.	274	153.3	18,000	27
Shandong Power Equipment Co.	776	2,435.4	115,061	140
Qindao Ventilator Co.	468	498.9	27,111	64
Zhaozhuang general Machinery Co.	516	482.1	102,087	54
Zhibe Ventilator Co.	326	128.2	19,200	28
Shandong Zhangquo Ventilator Co.	621	764.7	81,272	147
Weihai Ventilator Co.	156	189.2	25,020	32
Fuzhou Blower Co.	459	708	87,042	167
Fuzhou Chemical Machinery repairing Co.	316	103.77	14,904	44
Anhui Ventilator Co.	525	781.3	72,782	77
Nanchang Blower Co.	420	311.1	37,490	54
Pingxing South Coal Machine Co.	117	127	8,046	46

Table 3.64: cont'd

Name of Company	Employees	Fixed assets (Y 10,000)	Area m²	Production equipment (unit)
South Middle and South-West Area				
Wuhan Blower Co.	2,037	4,086	257,960	227
Wuhan Silencer Co.	358	51.23	7,000	13
Wuhan Ventilator Co.	219	262.2	12,335	41
Hubei Ventilator Co.	563	556.8	44,940	55
Yichang Blower Co.	91	62.12	7,425	35
Changsha Blower Co.	1,511	3,092.6	224,171	183
Changsha No. 2 Ventilator Co.	263	3098.9	61,000	57
Changsha Xiangjiang Ventilator Co.	249	178.2	64,119	50
Chongqing General Machinery Co.	3,288	5,044.3	305,471	290
Chongqing Blower Co.	298	222.3	16,112	34
Chongqing Jiangbei Ventilator Co.	314	187.1	7,710	30
Chengdu Power Machinery Co.	1,507	2,903.8	96,326	152
Chengdu Ventilator Co.	221	196.3	72,000	36
Sichuan Blower Co.	531	454.6	38,056	66
Sichuan Chunabei Ventilator Co.	186	290.5	25,000	42
Xiniang Blower Co.	517	465.2	52,043	58
Henan Zhoukou Ventilator Co.	656	556.9	56,916	80
Guiyang Blower Co.	324	155.2	7,000	47
Guiyang No. 2 Blowre Co.	303	263.5	51,200	56
Guangzhou Ventilator Co.	384	446.6	59,194	58
Foshan Ventilator Co.	439	570	81,000	100
Wuzhou Ventilator Co.	197	132.1	11,000	33
Dali general Machinery Co.	436	436.7	32,052	57
Gejiu Ventilating Machinery Co.	213	134.3	2,346	30

Pumps

3.281 The Chinese pump industry is very large, consisting of 923 enterprises employing 200,036 personnel in 1990 (excluding village level firms). There are over 20 million water pumps throughout the country and typically 4.2 million new pumps are made each year. The associated electricity consumption amounts to 20 percent of the national electricity demand: diesel powered pump sets consume about 5 percent of the national diesel oil consumption.

3.282 There is a wide variety of pumps made but single stage and single suction clean water pumps represent 50 percent of the output. There are around 100 pump manufacturers, amongst which there are estimated to be 16 major pump manufacturers with technology transfer arrangements with foreign firms (e.g., from the USA, Germany, UK, Australia, Switzerland and the former Czechoslovakia. Overall, the standard of Chinese pumps is judged to be at the level of western countries in the early 1980s. In terms of efficiencies, it is believed that the average test efficiencies of Chinese pumps are 2-5 percent lower than comparable foreign products. Nevertheless, the latest pump designs do represent a major improvement over older designs which are gradually being phased out.

Table 3.65: FAN PRODUCTION DATA

	1989	1990	1991
Centrifugal compressor	79	59	38
Axial flow compressor	3	3	1
Centrifugal blower	422	795	656
Roots blower	5,340	4,549	4,070
Vane type blower	257	126	154
Centrif. ventilator	116,737	97,432	99,830
Axial flow ventilator	51,973	48,141	42,289
Other types	9,238	22,608	38,135
Total	184,139	173,713	185,173

3.283 Unfortunately, the improvements in efficiency of many pump products on offer to the market may not be achieved by many users. Existing pumps are often incorrectly sized and operate well below design efficiency (sometimes at half the design figure). Manufacturing techniques vary greatly and there are still some enterprises making products at the level of western countries in the 1950s and 1960s. In such firms, the quality of internal castings is poor and the reject rate is 10-13 percent. The reject rate of impeller castings may reach 40 percent, while the comparable figure in western firms might be 3 percent. Low machining accuracy and large tolerances lead to higher materials and energy consumption of the manufacturers, and can contribute to a lower energy efficiency of the products also.

3.284 The potential for saving energy by pump users is substantial. The efficiency of new pump types is typically 5 to 10 percent better than older designs, better manufacturing techniques could give pumps with better performance characteristics, and proper application of pumps (e.g., correct type for the application, correctly sized) could add say 10-20 percent savings, a total of perhaps 30 percent energy savings.

Compressors

3.285 There are about 1 million compressors in China—excluding fans, blowers and refrigeration compressors—of which small units with capacity under 1 m^3 per minute represent 75 percent. Electricity consumption is about 9 percent of national demand, and domestically made compressors take 7 percent of the national electric motor production for motors in the range 0.2 to 4,000 kW.

3.286 There are 161 compressor manufacturers (including 7 key enterprises under the Ministry of Machinery) and 37 accessories plants. The most important firms are:

Key Enterprise	
Shenyang Gas Compressor Factory	B/L **
Shanghai Compressor Factory	B/L **
Huaxi General Machinery Company	B/L **
Beijing No.1 General Machinery Company	B/L **
Wuxi Compressor Works	A/M **
Bengbu Compressor Factory	A/M **
Liuzhou No.2 Air Compressor Factory	A/M **
Large Scale Plants	
Shenyang Air Compressor Factory	A/M **
Shanghai No.1 Compressor Factory	B/M **
Nanjing Compressor Factory	A/M **
Jiangxi Gas Compressor Factory	B/M **
Liuzhou Compressor Factory	A/M **
Xiangtan Compressor Factory	B/M **
Chongqing Gas Compressor Factory	B/M **
Yuyao General Machinery Factory	B/M
Changde General Machinery Factory	B/M
Zigong Compressor Factory	B/M

Classifications are: A/M Class A medium scale
B/L Class B large scale
B/M Class B medium scale

** Firms whose statistics are in Table 3.68 under "important firms."

3.287 In 1987, the China Compressor Association was established and this now has 131 members, including one research institute, two universities, and a range of manufacturers. The Association is subordinate to the China General Machinery Industry Association. Statistics for the compressor industry are presented in Table 3.68: the data are given for 85 firms in the information division of the Association for which statistics are collected routinely.

3.288 The overall efficiency of domestic compressors is now about the same as that for imported machines, although reliability and available accessories such as control systems do not match the imports. This is mainly because of poorer manufacturing processes and design factors. Many manufacturers use old and backward machining methods. As there are a large number of manufacturers in China, production batches are small and manufacturing costs are high, quality is unreliable and the manufacturing process itself consumes high amounts of energy. Quality variability can of course affect operating reliability adversely.

3.289 As an example of the problem of small-scale production, miniature air compressors may be quoted. The annual production is about 100,000 units from 80 plants. There are only 7 enterprises which produce more than 5,000 units per year:

Compressor Factory	Units made, 1991
Dafeng CF	18,171
Nanjing No.2 CF	8,380
Shanghai No.2 CF	7,185
Beijing Small Size CF	6,673
Shanghai Tonglian CF	6,467
Ma'anshan CF	5,998
Guangzhou Air CF	5,996
Total	58,870
Balance from 73 plants 73 x avg 560 units/yr	41,000

The 73 plants which produce relatively few units each year operate at relatively low production efficiency.

3.290 Although operating efficiency of domestic compressors are now quite good, it must be recognized that some older designs were rather poorer. Most old compressors remain in operation in Chinese factories. For example, about 50 percent of chemical fertilizer output comes from small-scale plants mostly using old types of compressor.

Phasing out such compressors could make a substantial contribution to energy savings in the chemicals industry.

3.291 In addition to checking the performance of the compressors themselves, it is important for manufacturing plants to ensure that drive motors are properly sized to match compressor characteristics. Indeed, a high efficiency compressor coupled with an inappropriate motor presents a good opportunity for energy saving.

Industrial Furnaces

3.292 The total energy consumption of industrial furnaces represents about one quarter of the national energy demand. Most furnaces are built for specific requirements and are non standard equipment. Since 1989, some supervision of furnace designs and performance has been exercised by the Industrial Furnace Institute of the Fifth Design and Research Institute affiliated to the Ministry of Machinery and Electronics Industry. There are about 200 furnace product manufacturing plants in China, most of them being small to medium-size enterprises or TVEs. There are no large-scale industrial furnace manufacturers yet.

3.293 There are more than 110,000 furnaces of various types in factories above the TVE level. The annual energy consumption of these is 160 million TCE. Including TVEs, the number of furnaces is about 180,000 consuming over 190 million TCE/year. A breakdown of industrial furnace users by type of industry is given in Table 3.66 and by type of furnace operation in Table 3.67.

Table 3.66: INDUSTRIAL FURNACES—NUMBER AND ENERGY CONSUMPTION IN MAJOR INDUSTRIES

Department	Number of industrial furnace and kiln			Energy consumption of furnace and kiln ($x10^4$ ton standard coal/yr)			The furnace energy consumption proportion to the total energy consumption of the department (%)	The proportion of furnace energy consumption of the department to the total of which in China (%)
	Electric furnace	Fuel furnace	Sum	Electric furnace	Fuel furnace	Sum		
Metallurgy	730	4,147	4,877	335.0	4,083.00	4,418.00	79.60	27.30
Nonferrous metal	2,202	448	2,650	194.76	154.86	349.62	33.81	2.16
Building material	196	15,733	15,969	67.6	5,331.58	5,399.18	87.70	33.36
Light industry	17	5,467	5,484	69.38	605.54	674.92	15.04	4.17
Chemical industry	511	8,177	8,688	401.00	3,726.00	4,127.00	53.00	25.50
Oil chemistry		611	611		539.80	539.80	35.80	3.34
Machinery	19,467	18,120	37,587	131.19	328.27	459.46	33.00	2.84
Weapon	8,260	1,732	9,992	31.36	43.51	74.87	20.74	0.47
Aviation	9,117	988	10,105	11.80	11.60	32.40	21.70	0.15
Shipping	1,472	793	2,265	1.20	8.40	9.60	19.32	0.06
Railway	3,345	4,960	8,305	16.28	48.72	65.00	2.80	0.41
Electronics	6,600	520	7,120	15.50	23.30	37.80	31.50	0.24
Total	51,917	1,736	113,653	1,275.07	14,903.58	16,178.65	56.54	100.00

Table 3.67: ENERGY CONSUMED BY VARIOUS TYPES OF FURNACE AND KILN

Kind of furnace	Energy consumption x 10^4 tons standard coal/yr	Proportion of the total %
Firing furnace & kiln	5,688.66	35.16
Smelting furnace & kiln	4,258.86	26.32
Chemical industry furnace & kiln	3,498.19	21.62
Furnace for metal reheating	695.73	4.30
Oil chemistry heating furnace & kiln	610.00	3.77
Sintering furnace & kiln	592.40	3.66
Heat-treatment furnace & kiln	229.49	1.42
Roasting furnace & kiln	193.34	1.20
Drying furnace & kiln	93.78	0.58
Others	318.20	1.97
Total	**16,178.65**	**100.00**

3.294 In general, the energy consumption of furnaces in China is much higher than in comparable operations in developed countries. For example, electric furnaces for steel production consume on average about 300 kWh/t of product, around 50 percent higher than typical electric furnaces in developed countries. It is estimated that energy savings from the adoption of better furnace designs and their correct operation could amount—in many industries—to about 30 percent.

3.295 To achieve such savings, many measures need to be taken. For example, combustion control needs to be improved. New burner designs are needed, to improve air/fuel mixing and to allow more rapid furnace warm-up times. The use of computer controls may be justified on larger equipment. Heat recovery from exhaust gases could be applied on many furnaces, with the recovered energy used to preheat incoming combustion air. Better refractories need to be used to line furnaces to reduce heat losses from the structure itself.

3.296 While the benefits of these and other measures are generally well known, improved technologies are limited in application for a number of reasons:

(a) Industrial enterprises are short of investment funds.
(b) Enterprise managements are often unaware of the potential benefits.
(c) There is a lack of technical manpower at enterprises to design and implement improvements.

(d) Incentives to plant personnel to save energy in furnace operations are absent.

Steam Systems and Traps

3.297 The efficient distribution of steam or hot water from boilers to the users is a major factor in the energy consumption of most enterprises. Compared with developed countries, the overall efficiency of steam systems is rather low. Some typical figures illustrate the differences:

	China	W Europe
* Steam generation	55-60%	80-90%
Distribution piping	85-90%	95-98%
Combined efficiency	46-54%	76-88%
* Steam using equipment, say	35-40%	60-70%
* Overall system efficiency	16-22%	45-62%

Boiler operation is clearly a major area for improvement. However, the potential for energy saving is also significant through the reduction of losses in the distribution system itself. These losses result from a combination of poor insulation, incorrect pipe diameters, inappropriate piping layouts, and poor condensate drainage and air venting caused by insufficient or poorly performing steam traps. There is also a lack of certain types of auxiliary equipment, such as automatic condensate pumps.

3.298 There are about 45 steam trap manufacturing plants in China. The traps available from Chinese manufacturers are often not well made and have short service lives (say 3-4 months compared with a European, Japanese or US steam trap which would last say 1-2 years in the same duty). The poor trap quality causes additional maintenance and many users prefer not to replace a defective trap or do not install a trap at all where one is really needed. There is a lack of customer service orientation by the trap manufacturers, with little assistance to customers to select the right type and size of trap, insufficient marketing effort, and little or no after sales service.

3.299 There is therefore a major opportunity to save energy by the promotion of better distribution systems and better steam traps. Through these measures, savings of at least 10 percent of the steam currently generated should be easily achieved over the next 5-10 years for relatively little capital expenditure.

Boilers

3.300 There are about 430,000 industrial steam boilers in China—excluding those used in power plants, locomotives and ships—and these consume 300 million TCE while producing up to 980,000 tons per hour of steam or steam equivalent. The energy consumed is about one third of the national energy demand. The importance of efficient boilers is therefore obvious and a special study was carried out on this topic in conjunction with the Greenhouse Gas Project.

3.301 The report of the boiler study provides comprehensive data on industrial boilers in service in China and most of these data are not repeated here. However, a few important facts may be summarized as follows:

(a) There are 280,000 steam boilers with a thermal capacity of 700,000 tph of steam. There are 150,000 hot water boilers with a thermal output of 200,000 MW (28.5 percent of the total thermal capacity of boilers). Boilers are widely distributed throughout China (Table 3.69).

(b) Of these boilers, process industries use 195,000 units (580,000 tph) while the residential sector uses 235,000 units (400,000 tph or equivalent).

(c) The most widely used type of industrial boiler is a horizontal packaged boiler based on a combined water tube and fire tube design, representing more than 60 percent of the existing stock. Water tube boilers represent about 25 percent of thermal capacity, and small vertical boilers of various types represent about 15-20 percent.

(d) Boilers fired by chain grate stokers are almost 60 percent of capacity and 65 percent of the number of units. Reciprocating grate stokers represent about 20-25 percent, spreader stokers less than 1 percent. The remaining capacity is mostly hand stoked boilers.

(e) Almost all industrial boilers fire raw, unwashed coal. About 5 percent of the capacity fires oil or gas. Of the coal fired in boilers, the following breakdown is estimated:

Type of coal	Percent of capacity
Bituminous coal	75.6
Anthracite	9.7
Low grade coal	9.1
Lignite	5.6

Table 3.68: STATISTICS ON COMPRESSOR MANUFACTURE, 1987-1991
Data for 85 firms in the statistics network of the China Compressor Association.

	1987	1988	1989	1990	1991
Industry gross production value, Y 10^6					
85 firms	850.9	1,026.4	1,096.1	1,261.1	1,440.1
14 important firms	442.1	518.5	613.5	813.6	795.2
Average workers					
85 firms	61,197	61,802	62,789	62,564	63,220
14 firms	26,094	26,582	30,171	30,291	31,138
Metal working machines					
85 firms	9,096	8,931	9,706	9,351	9,262
14 firms	3,598	3,424	3,907	3,957	3,898
Castings, tonnes acceptable					
85 firms	43,754	50,369	48,089	37,976	40,719
14 firms	25,180	29,048	30,440	24,525	26,063
Castings, tonnes unaccept.					
85 firms	5,239	6,555	6,545	5,064	5,009
14 firms	3,107	3,482	3,876	3,248	3,119
Steel used, tonnes (% utilised)					
85 firms	49,078	50,923	46,730	38,739	43,900
	(63.4)	(64.5)	(64.6)	(66.1)	(65.5)
14 firms	22,213	22,734	21,961	17,887	20,293
	(59.6)	(63.6)	(65.0)	(64.8)	(64.2)
Energy use, TCE					
85 firms	124,017	122,805	119,750	104,978	112,926
14 firms	60,392	64,208	70,031	60,446	64,092
Energy use, 103 kWh					
85 firms	84,079	86,035	83,607	74,929	82,276
14 firms	44,204	43,641	47,034	40,678	45,953
Production, Total compressors					
85 firms units	135,423	126,040	122,203	113,428	114,139
10^3 kW	1,456.9	1,789.4	1,736.5	1,516.0	1,554.8
14 firms units	8,604	8,892	10,459	9,061	9,316
10^3 kW	755.1	932.5	1,001.9	850.4	804.1

Table 3.69: STATISTICS ON THE EXISTING INDUSTRIAL BOILER STOCK

Region	IB quantities (sets)					IB evaporation capacity (t/h)				
	Home	Production	Total	Steam	Hot water	Home	Production	Total	Steam	Hot water
Nation total	**2236,300**	**195,801**	**432,101**	**282,475**	**149,626**	**400,544**	**582,541**	**983,085**	**702,466**	**280,619**
Beijing	14,025	6,813	20,838	7,857	12,981	31,621	20,794	52,415	22,878	29,537
Tianjing	8,021	6,264	14,276	9,201	5,066	11,093	12,808	23,901	17,124	29,537
Hebei	16,412	14,540	30,952	17,650	13,302	29,994	40,357	70,351	46,342	24,009
Shanxi	11,755	6,545	18,300	10,470	7,830	35,301	22,125	57,426	37,963	19,463
Neimeng	12,728	4,383	17,111	5,677	11,434	22,933	12,514	35,447	14,274	21,173
Liaoning	31,465	13,403	44,868	20,984	23,884	61,647	47,353	109,000	56,420	52,580
Jilin	18,573	7,478	26,051	9,279	16,772	28,693	32,511	61,204	35,085	26,119
Heilongjiang	35,541	10,177	45,688	13,752	31,966	52,521	26,921	79,442	34,368	45,074
Shanghai	3,720	6,495	10,215	10,191	24	1,521	9,294	10,815	10,805	10
Jiangsu	6,444	17,764	24,208	23,865	243	5,473	38,153	43,626	42,842	784
Zhejiang	6,973	9,358	16,311	16,320	11	2,420	16,773	19,193	19,126	67
Anhui	3,432	4,685	8,117	8,020	97	4,181	13,036	17,217	16,936	231
Fujian	1,843	4,541	6,384	6,326	58	1,036	9,619	10,655	10,638	17
Jangxi	3,470	4,693	8,163	7,899	264	2,760	13,670	16,430	16,389	41
Shandong	14,418	16,457	30,875	23,337	7,538	22,831	48,154	70,895	56,435	144,550
Henan	5,023	10,864	15,890	15,010	877	10,669	29,940	40,609	38,238	2,371
Hubei	4,622	7,472	12,094	11,526	568	11,676	18,736	30,412	29,443	969
Hunan	7,466	7,195	14,661	14,521	40	8,103	26,971	35,074	34,954	120
Guangdong	1,438	7,561	8,999	8,143	856	1,351	22,879	24,230	24,111	119
Guangxi	1,649	3,460	5,109	5,105	4	1,709	11,301	13,010	13,007	3
Hainan	34	375	409	407	2	40	689	729	728	1
Sichuan	3,387	8,851	12,238	12,091	147	3,376	25,341	28,717	28,573	144
Guizhou	2,094	2,153	4,247	4,140	107	2,781	6,010	8,791	8,661	130
Yunnan	3,528	3,046	6,574	4,759	1,805	2,580	21,691	24,271	23,908	363
Xizang	367	135	502	454	48	589	597	1,286	1,159	127
Shanxi	3,622	4,807	8,429	6,811	1,,618	9,056	13,133	22,189	19,433	2,756
Gansu	4,755	3,624	8,379	4,241	4,138	9,910	18,059	27,969	19,152	8,817
Qianghai	1,786	707	2,493	1,505	988	4,581	2,480	7,061	4,144	2,917
Ningxia	1,755	902	2,657	1,314	1,343	4,725	3,619	8,345	4,652	3,693
Xinjiang	5,963	1,053	7,016	1,501	5,515	15,321	18,439	33,760	20,753	13,007

(f) The existing stock is dominated by medium and small boilers. A survey of 13,930 boilers in Beijing showed:

Evaporation rate tph	Percent of capacity
< 1	12.9
2-4	65.4
> 6	21.7

(g) Boilers often operate under low load conditions, high carbon levels in the ash, high excess air ratios and high stack gas temperatures. As a result, combustion efficiencies are usually low. Various surveys of hundreds of boilers in Guangzhou, Lanzhou and Shanghai, for example, show that the typical combustion efficiency ranges from 50-78 percent, even though prototype testing gave results 10-15 percent higher. Table 3.70 presents the results of some of these surveys.

(h) With respect to pollutant emissions, coal consumption is about 30 percent of the national total while dust emissions from boilers are about 36.6 percent of the total, SO_2 emissions are 38.8 percent and CO_2 emissions are over 500 million tpy.

3.302 While the boiler study identifies some technical areas where improvements can be made to new boiler designs, there could be substantial improvements in the operation of existing boilers. Proper attention to combustion control, and a greater availability of gas testing equipment for routine monitoring of boiler conditions, should allow low cost savings to be achieved in the near term, mostly without capital investment. Operator training and improved energy management are needed.

Potential for Improvements

3.303 The improvements in energy efficiency in manufacturing enterprises that could come from the adoption of more efficient equipment and equipment that is properly sized for its application (as well as properly operated and maintained) are believed to be substantial. Of course, the magnitudes of these improvements are highly variable from enterprise to enterprise and it is impossible to generalize—every case is different. As a general rule however, those responsible for the specifying and purchasing of major items of equipment need to be more aware of technical developments in equipment designs and must be diligent in seeking higher performance equipment.

3.304 Capital costs should be considered in conjunction with operating costs so that full consideration is given to more expensive but more efficient equipment. The principle of life cycle costing and the selection of equipment based on economic evaluations need to become standard practice: lowest first cost should not be the selection criterion. Above all, the customer must learn how to influence product quality and product characteristics, while manufacturers need to adopt a more service-oriented approach to survive and prosper in a market environment.

3.305 Although many beneficial changes will occur under the influence of the market, government policies and regulations can promote faster changes. For example, stricter enforcement should be ensured of regulations prohibiting the manufacture and sale of electric motors made to out-dated standards. Fiscal incentives should be considered to help enterprises justify more rapid replacement of old equipment using backward technologies. Financial support should be considered for research and development on energy efficient products, and for popularization of new and efficient products.

Generic Investment Options

3.306 The energy efficiency measures selected for study in this sector—from a great many possible measures in a very complex sector—were the following:

Table 3.70: TYPICAL BOILER OPERATING DATA IN MAJOR CITIES

Operational Thermal Efficiency of Industrial Boilers in Guangzhou City

No.	Boiler type	Sets	Measured efficiency (%)	
			Average	Minimum
1	Hand-fired boiler	20	50.5	45.0
2	Reciprocating grate	101	64.7	43.3
3	FBC	11	65.8	61.5
4	Chain grate	22	69.9	65.1
5	Pulverized coal	21	77.6	71.8
6	Oil fired	26	81.7	67.0
7	Others	11	62.1	58.4

Actual Measured Results of IB in Lanzhou City

No.	Item	Boiler (t/h)					
		<0.5	1	2	4	6	10
1	Sets measured	3	11	55	75	5	1
2	Local capacity (t/h)	1.2	11	113	300	32	10
3	Average output of boiler (t/h)	0.39	0.73	1.21	2.37	5.06	5.81
4	Flue gas temperature °C	211	139	134	145	133	128
	Max (°C)	297	211	212	210	169	128
	Min (°C)	139	76	96	78	98	-
5	Excess air ratio (α)	2.97	2.73	3.28	3.48	3.36	3.37
	Max	3.73	6.79	5.53	5.88	5.13	3.37
	Min	2.03	1.68	1.79	2.10	1.90	-
6	Carbon content of slag (%)	20.5	27.6	18.9	23.4	25.4	18.2
	Max (%)	58.7	66.5	59.6	57.6	32.1	18.2
	Min (%)	2.64	2.35	2.71	3.03	16.7	-
7	Heat efficiency of boiler (%)	63.5	67.2	68	69.7	72.2	74.5
	Max (%)	69.9	76.3	75.07	81.0	78.0	74.5
	Min (%)	64.1	54.3	52.3	55.3	60.0	-

Measured Thermal Efficiencies of Industrial Boilers in Shanghai

Year	Item	Boiler (t/h)					
		<1	1	2	4	>6	Total
1987	Number (sets)	59	46	71	89	77	283
	Mean heat eff. (%)	60.86	67.27	68.70	70.49	65.51	-
1988	Number (sets)	39	50	63	105	17	274
	Mean heat eff. (%)	61.31	65.80	68.93	70.71	70.19	-
1989	Number (sets)	46	47	40	66	13	212
	Mean heat eff. (%)	62.58	68.15	68.78	71.99	74.02	-
1990	Number (sets)	32	37	32	61	7	169
	Mean heat eff. (%)	62.05	70.88	70.35	73.14	75.77	-
1991	Number (sets)	38	36	37	42	27	180
	Mean heat eff. (%)	77.26	68.41	72.59	72.55	73.74	-
5 years	Number (sets)	214	216	243	363	81	1,117
	Mean heat eff. (%)	64.8	68.1	69.9	71.8	72.1	-

E1 High efficiency electric motors

The annual output of small and medium size three phase induction motors (0.5 to 1000 kW) runs at about 3.5 GW of which 3.1 GW are under 200 kW size. Electricity consumption in all these small and medium size motors is estimated to be 60 percent of total industry electricity consumption. About 70 percent of the existing motor inventory is from the old J series (typical of the motors made in developed countries 30 years ago) and about 30 percent are Y series (typical of motors from 20 years ago). The efficiency of such motors ranges from 2 to 5 percentage points below modern standards in the USA, Europe and Japan. New designs of motors with higher efficiency are now manufactured in China (the YX series) and, in sizes above say 15 kW, these have efficiencies around 3 percentage points better than the conventional Y series used for most industrial applications.

E2 Variable speed motors

Fans and pumps have an installed motor capacity of 90 GW or 27 percent of the national total, consuming 165 TWh or 31 percent of national electricity consumption. It is estimated that at least 50 percent of these fans and pumps operate under conditions of variable load and throughput, mostly controlled by baffles or valves in an energy -inefficient manner. Recycling from the pump discharge side to the suction side is also common, resulting in waste of electricity. By introducing variable speed drives for fans and pumps, lower throughputs could be achieved while using less electricity: exact savings depend on the load profile of the particular application but 20-30 percent is often possible. Variable speed motors are made in China but output is limited. Many motors use an electromagnetic clutch for stepless speed variation or pole changing motors (2 speed, 3 speed, 4 speed). Variable frequency systems are generally imported and are costly (although usually more efficient).

E3 Electric motor repair centers

Of the total installed capacity of electric motors of about 330 GW, about 10 GW or 3 percent are repaired each year. Repairs are mainly rewinding, estimated at 80 percent of all work. There are no specialized rewinding companies in China at present, and larger motors are often sent back to the manufacturer for repair. Smaller motors are repaired by a wide variety of workshops or enterprises. Most use crude equipment for burning off the old motor windings and do not work to strict technical specifications. There is no means of checking the efficiency of the rewound motors. An investigation of the effectiveness of repairs showed that the drop in efficiency averaged about 1 percent, with the greatest decrease—almost 2 percent—for the smallest motors. A significant improvement in rewinding practices is possible and this could have an impact on electricity consumption in all industries.

E4 Steam trap production

About 300 million tons of coal are consumed annually to produce over 800,000 tons of steam per hour. Boiler efficiency is clearly important but a major factor is also the proper operation of steam distribution and condensate recovery systems in industrial plants (as indicated by figures given previously, the overall efficiency of steam systems is around 20 percent). A key element is the steam trap: Chinese-made traps are often of outdated design, poorly machined and have a short service life. It is estimated that under 10 percent of the traps needed for effective steam system operation are actually installed. The upgrading of steam trap production could therefore help all industries to save steam and thus to save boiler fuel on a large scale.

3.307 Based on data obtained from motor manufacturers and research institutes, the above measures were examined and the benefits to electric motor and steam trap users were evaluated. Other than for the establishment of motor repair centers, the rate of return for an investment in the measures listed is dependent on the specific situation of the user. In general, it is believed that most of the measures can give good payback periods for industrial enterprises but that more promotional efforts are needed to encourage greater levels of adoption.

3.308 With respect to the motor repair centers, the calculated rate of return and payback (including construction time) are as follows:

	IRR percent	Payback, years
E3 Motor repair centers	45	4

3.309 Forecasts of the potential extent of application of each measure were made for business as usual and accelerated scenarios. For E1 and E2, the figures given are for new motors sold (expressed as MW/year) over and above present levels. For E3, the figures are for the capacity of motors repaired annually (MW/yr). For E4, the figures are for the number of steam traps made above present levels. The forecasts are:

	1990	2000	2010
E1 High Efficiency Motors (MW/yr)			
BAU motor capacity sold	0	2,500	15,000
Accel. motor cap. sold	0	5,000	25,000
E2 Variable Speed Motors (MW/yr)			
BAU motor capacity sold	0	1,000	3,000
Accel.motor cap. sold	0	1,500	4,500
E3 Motor Repair Centers (MW/yr)			
BAU repair capacity	0	2,500	5,000
Accel.repair capacity	0	3,500	8,000
E4 Steam Traps (million items per year)			
BAU extra traps made	0	2	10
Accel.extra traps made	0	4	10

3.310 Details of the assumptions made and the energy and emissions factors used in the calculations are given in Appendix A.

Projected Impacts on Energy and Emissions

3.311 Using the forecasts indicated, the following are the expected impacts on energy consumption in China by users of the improved equipment:

	Savings 10^3 TCE/yr by 2000		Savings 10^3 TCE/yr by 2010	
	BAU	Accel.	BAU	Accel.
E1 High efficiency motors	103	206	618	1,029
E2 Variable speed motors	247	370	741	1,111
E3 Motor repair centers	55	73	110	176
E4 Steam traps	2,000	4,000	10,000	10,000

3.312 Similarly, expected impacts on greenhouse gas emissions are indicated in terms of the reduced tonnages of CO_2:

	CO_2 reduction 10^3 TPY by 2000		CO_2 reduction 10^3 TPY by 2010	
	BAU	Accel.	BAU	Accel.
E1 High efficiency motors	65	131	392	653
E2 Var. speed motors	157	235	470	705
E3 Motor repair centers	35	49	70	111
E4 Steam traps	1,302	2,604	6,510	6,510

Emissions

3.313 For this sector—the manufacture of equipment—no emissions were reported or estimated as the sector itself is not a major user of energy and pollutant emissions are not large. The impacts on energy use and CO_2 emissions estimated in the previous section are therefore expected to be observed as changes in other sectors throughout the economy—sectors that use electric motors or employ steam traps.

4. COAL MINING INDUSTRY

A. INDUSTRY PROFILE AND PRODUCTS

4.1 Coal is of course the most important energy source in China and the coal mining industry is therefore a key contributor to the national economy. In 1992, the total production of raw coal reached 1.11 billion tons. The coal mining industry is itself a major energy consumer for coal mine exploration, mine construction and coal production, washing, preparation and transportation. Significant energy is also consumed in subsidiary enterprises such as service trades to the mines and to the industry personnel.

4.2 Coal mining in China is conducted by both state-owned enterprises and enterprises owned by local collectives (TVEs). To improve the economic performance of many coal mining departments, their business activities have broadened in recent years. In addition to coal production, many enterprises undertake such activities as electricity generation, coking, coal gasification, coal processing, chemicals production, and utilization of minerals associated with coal mining. At present, there are 21,037 enterprises in the coal industry employing 7 million persons and operating the following facilities, singly or in combinations:

Mines, state owned	1,866
Mines, local collectives	17,408
Coal washing plants	about 300
Machinery plants	over 190
Power stations using gangue	60
Power stations using coal	30
Building material plants using gangue and wastes	about 300
Service enterprises, other businesses	over 2000

4.3 Within these enterprises, there are 21 with an annual coal production capacity of over 10 million tons, 12 with over 5 million tons and 18 with over 3 million tons. Collective-owned mines generally use hand mining methods and their productivity is particularly low. Amongst larger state-owned mines, two thirds are using mechanical mining techniques and one third have fully integrated mechanical mining systems. However, it is estimated that about one third of the machinery in even the larger state-owned mines can be considered backward, using old out-of-date technology and consuming large amounts of energy.

4.4 By 1990, the coal washing capability of key coal mines reached 223.6 million tons per year, annually disposing of wastes of about 37.4 million tons. The energy saved in coal transport is estimated to be about 13.6 million TCE per year.

B. ENERGY USE

4.5 Energy consumed in the industry is mainly in the form of coal and electricity, with typically about 2 percent as petroleum-based fuels. A breakdown of energy consumption from 1980 to 1992 is shown in Table 4.1. A significant amount of the coal is used in small-scale boilers scattered around the enterprise sites. A total of 15,500 small boilers are in service, with a steam raising capacity of about 47,000 t/h and consuming about 10 million tons of coal annually.

Table 4.1: ENERGY CONSUMPTION OF MAJOR COAL MINES, 1980-92

	Raw coal		Electricity		Petroleum products		Total energy
	10^6 t	%	GWh	%	10^3 t	%	10^6 TCE
1980	12.60	62.95	1,170	35.47	15	1.58	13.95
1981	13.00	65.09	1,179	33.26	16	1.65	14.32
1982	13.52	65.05	1,236	33.45	15	1.50	14.93
1983	14.09	64.78	1,299	33.62	17	1.60	15.61
1984	15.77	65.47	1,423	33.00	18	1.53	17.30
1985	15.52	64.06	1,511	34.68	15	1.26	17.60
1986	15.52	61.97	1,609	36.11	19	1.56	18.00
1987	14.46	60.00	1,651	37.90	25	2.10	17.60
1988	15.03	59.20	1,732	38.60	27	2.20	18.13
1989	16.24	58.23	1,955	39.67	28	2.10	19.91
1990	18.77	58.79	2,198	38.95	35	2.26	22.80
1991	16.40	54.33	2,264	43.43	32	2.24	21.06
1992	17.92	56.50	2,324	41.48	31	2.02	22.64

Note: These data were provided by the Energy Conservation Office of the coal industry and do not include the energy consumed in coal washing plants.

C. ENERGY EFFICIENCY

4.6 Energy consumptions per ton of coal output from 1980 to 1992 are shown in Table 4.2. There are of course many factors affecting the development, efficiency and energy consumption of the coal mining industry. For example, some of the more important factors are as follows:

(a) **Location within China.** South of the Huanghe or Yellow River, there is no energy required for space heating in the winter months, in contrast with the need for heating in the northeast and northwest of the country. As an example of the internal use of coal, the Mongolian Integrated Coal Company in the northeast produces over 110 million tons per year of coal but uses 7.5 million tons of this for its own purposes.

Table 4.2: SPECIFIC ENERGY CONSUMPTIONS OF MAJOR STATE-OWNED COAL MINES, 1980-92

	Raw coal output 10^6 t	Coal consumption $t/10^6$ t	Electricity consumption kWh/t
1980	344.39	36,586	33.97
1981	335.05	38,800	35.19
1982	349.90	38,640	35.32
1983	363.12	38,803	35.77
1984	394.70	39,954	36.05
1985	406.26	38,202	37.19
1986	413.92	37,495	38.87
1987	427.98	33,787	38.58
1988	435.79	34,489	39.74
1989	462.35	35,125	42.28
1990	492.54	38,109	44.63
1991	505.00	32,475	44.83
1992	476.00	37,647	48.82

(b) **The Hydrogeological Conditions.** Mines exploiting thin coal seams at great depths, needing to pump water out regularly, and with large quantities of associated gas necessitating high ventilation rates, will clearly consume relatively high amounts of energy.

(c) **Period of Mine Exploitation.** At the beginning of the working life of a mine, before full production is reached, or at the end of the working life as the coal seams are worked out, energy consumption per ton of useful product will be high.

(d) **Status of Mining Equipment.** In the older mines, the equipment used for mining and for associated services will generally use inefficient technology and be wasteful of energy, compared with new mines using up-to-date mechanized mining methods.

(e) **Energy Management.** Mining enterprises can vary greatly in their levels of professional management, of measuring equipment and of modern instrumentation for monitoring performance.

In general, the use of energy in the Chinese coal mining industry can be considered somewhat inefficient and below the average levels of efficiency found in most large-scale enterprises in the country.

D. Energy Efficiency Measures

4.7 From 1981 to 1990, a total investment of Y 1.62 billion was made in key coal mines for energy saving measures and energy efficient technologies. This investment brought energy savings of almost 8 million TCE, representing an investment of Y 203 per TCE. The measures applied to save energy included the following:

(a) **Electric Motor Applications**

Typical measures are replacing ventilation fan blades with more efficient designs, applying modified designs of drainage pumps, and adjusting electric motor speeds by electronic devices and hydraulic coupling systems.These and similar measures have resulted in the renewal of over 30,000 high energy consuming mechanical and electrical items, saving up to 0.5 billion kWh per year.

(b) **Coal Mine Gases**

There are 43 gas utilization systems in operation and 355,500 families using the gas: the annual methane consumption is 0.36 million m^3 and the annual savings equivalent to 600,000 TCE.

(c) **Coal Briquetting**

About 160 coal briquetting plants have been established with an annual output of 1.2 million tons. The energy savings are estimated to be 550,000 TCE per year, due to the reuse of coal fines and the more efficient use of the briquettes.

(d) **District Heating**

District heating systems have been expanded, covering an area of 8 million m^2 and saving 550,000 TCE/yr.

(e) **Cogeneration**

A major power plant at Kailuan coal mine has converted to cogeneration operation from the conventional condensing mode, producing electricity and heat for various uses including district heating in the Linxi area. The heat supply has allowed 38 small boilers to be replaced: since 1982, the accumulated coal savings have reached 415,000 tons of coal and electricity savings 10.1 million kWh.

(f) **Use of Coal Wastes**

Coal waste-fired power plants now amount to 57 plants with a total installed capacity of 533 MW.

4.8 In spite of these successes, there are currently shortages of funds for investment in energy saving and some regions in particular are seeing very little investment. There are no laws or regulations for energy saving and energy efficiency does not feature in coal mine designs. Even new coal mines include obsolescent, high energy consuming equipment.

E. Potential for Improvement

4.9 Measures already adopted in the industry, as indicated above, will continue to be made. Old and outdated technologies will be replaced by modern energy efficient technologies and equipment. For example, ventilation fans generally account for 15-30 percent of total electricity consumption in coal production, and sometimes as much as 40 percent. Statistics for ventilation fans in 1990 show that there are large numbers of fans installed —50,775 units in coal mines owned by county or higher level governments and 2864 main ventilator fans in key coal mines. Under 5 percent of these fans reach advanced national or international standards, indicating a major opportunity for energy saving by replacing outdated equipment. In conjunction with improved fan equipment, further application of variable speed drives can be expected to better match fan output with system requirements, and thus to save energy.

4.10 Another example for the application of modern equipment is water pumps, whose motors use about 10-30 percent of total electricity consumption in coal production, rising to 80 percent in extreme cases. Key coal mines use 27 percent of total electricity or 2.5 billion kWh annually, representing about 5 kWh per ton of coal produced. Coal mines owned by county and higher level governments have installed 85,519 pumps, dominated by units made in the 1950s and 1960s. Drainage systems typically run at efficiencies of 30-40 percent, offering another opportunity for large electricity savings through updating of equipment.

4.11 Use of coal wastes will be increased, as there are over 50 million tpy of washed coal wastes and 5.5 million tpy of coal muds available for exploitation. This quantity of wastes—with some additional low to middle quality coals—could be applied to electricity generation in cogeneration stations with installed capacities totalling about 3,000 MW. The coal savings could be in excess of 10 million tpy.

4.12 Extension of coal washing capacity is also expected. Doubling capacity to say 450 million tpy by 2000 would result in 75 million tpy coal wastes being removed and transportation energy equivalent to about 27 million TCE per year being saved. Better classification of coal into narrower size ranges is likely to be used increasingly to provide a better quality product for customers and to help them utilize the coal more efficiently.

4.13 Modern mining technologies and procedures will be applied, including more strip mining of surface or shallow coal seems. Strip mining is estimated to save 30 percent over conventional deep mining.

F. The Environmental Situation

4.14 All coal mining areas in China have been severely polluted, showing the detrimental effects of water and air pollution and of solid waste in various forms. The effect of air pollution in particular is seen in the higher incidence of respiratory problems in the local population, and higher cancer rates are being observed.

4.15 Water pollution is seen in the destruction of underground water formations and their contamination by dirty surface drainage. This dirty water can come from many sources, such as pit drainage water, effluent from coal washing plants, and water from coking plants (e.g., water used to quench coke), with the latter particularly prone to contamination by toxic chemicals released in the coke-making process.

4.16 Air pollution is caused by the combustion of coal in boilers, heating stoves for living areas, power plants, coking plants, coal gasification plants, and associated operations such as brick ovens, cement mills and machinery maintenance facilities. The efficiency of coal mine enterprise boilers is typically 50-60 percent, as much of the equipment is very old. Table 4.3 shows the trends in major air pollutant emissions for the largest state-owned coal mines.

4.17 In addition to the emissions quoted, the self-combustion of gangue residues produces a large amount of pollution by SO_2 and CO_2. Another source of air pollution is the release of coal mine gas: each year, about 500 million m^3 of gas are pumped out of pits but only 290 million m^3 are used, the remainder being discharged to atmosphere. Typically, this gas has a high methane content.

4.18 Solid wastes are mainly derived from dusts and residues obtained from coal screening, washing, gasification, coking, cement processing, power plants and transportation. It is estimated that about 0.3 million tons of dust are emitted into the air by major state-owned coal mines each year, 4.7 million tons of ash discharged from boilerhouses, and 5 million tons of gangue from coal washing plants. By 1992, the accumulation of gangue in coal mines had reached about 200 million tons.

Table 4.3: ESTIMATED DISCHARGES OF SO_2 AND CO_2 FROM MAJOR COAL MINES, 1980-92

	SO_2 10^6 t	CO_2 10^6 t
1980	0.252	5.54
1981	0.260	5.72
1982	0.270	5.95
1983	0.282	6.20
1984	0.315	6.94
1985	0.310	6.83
1986	0.310	6.83
1987	0.289	6.36
1988	0.300	6.61
1989	0.324	7.15
1990	0.375	8.26
1991	0.328	7.22
1992	0.360	7.92
Average	0.310	6.73

5. POWER SECTOR

A. SECTOR PROFILE

5.1 The Chinese power generation sector is based predominantly on coal, this resource representing about 90 percent of the energy used in power stations. The total installed generating capacity has now exceeded 166,000 MW, included in which is a contribution of hydroelectric power of over 40,000 MW. The total electricity generated is in excess of 750 TWh and this has been growing at about 8 percent annually for the last 10 years. Recent figures for generating capacity and power generated are as follows:

	Installed generating capacity MW Of which		Power generated 10^9 kWh per year of which:	
	Total	Hydro.	Total	Hydro.
1980	65,270	20,230	300.6	58.2
1985	87,050	26,420	410.7	92.4
1986	93,819	27,542	449.6	94.5
1987	102,897	30,193	497.2	100.3
1988	115,497	32,698	545.1	109.2
1990	137,890	36,046	621.3	126.4
1991	151,473	37,884	677.6	125.1
1992	166,532	40,680	754.2	131.5

5.2 Although there remain shortages of electricity in many parts of the country, the growth in generating capacity is now keeping up with the growth of national income and with the overall increase in energy consumption:

	National income growth %	Energy production increase %	Energy consumption increase %	Electricity consumption growth %
1985	13.5	9.9	8.2	9.0
1986	7.7	3.0	5.4	9.5
1987	10.2	3.6	7.2	10.6
1988	11.3	5.0	7.4	9.7
1989	3.7	6.0	4.2	7.3
1990	4.8	2.3	1.8	6.2

Some imbalances in the situations in various parts of China are shown in the following figures for 1990:

Region	GNP		Energy production		Electricity consumption	
	Y 10^9	%	10^6 TCE	%	TWh	%
East	923.4	53.3	256.6	25.6	310.5	49.8
Central	512.8	28.9	558.5	53.7	202.4	32.5
West	281.0	15.8	196.4	18.9	109.3	17.5

The distribution of power plant units by size at the end of 1990 was as follows:

Size, size range	%
< 50 MW, low pressure units	22.6
< 50 MW, high pressure units	9.8
Cogeneration systems	9.1
100 - 110 MW	11.5
125 MW	8.6
200 - 210 MW	23.0
250 - 350 MW	14.2
500 - 600 MW	1.2
Total	100.0

By the end of 1992, there were 26 power plants, including both thermal and hydro plants, with total capacity over 1,000 MW. These plants are:

Name	MW	Name	MW
Hydroelectric:			
Gezhouba	2,715	Longyangxia	1,280
Baishan	1,400	Liujiaxia	1,225
Thermal:			
Jianbi	1,625	Shidongkou	1,200
Douhe	1,550	Shidongkou #2	1,200
Qinghe	1,300	Dagang	12,00
Shengtou	1,300	Huangpu	1,100
Xuzhou	1,300	Wangting	1,100
Pingyu	1,200	Xingtai	1,090
Datong	1,200	Qinling	1,050
Jinzhou	1,200	Liaoning	1,050
Fulaerji #2	1,200	Zhenhai	1,050
Zouxian	1,200	Zhangze	1,040
Yaomeng	1,200	Jiaozuo	1,024

5.3 With respect to power grids, there are thirteen large grids with capacities in excess of 1 GW. There are over 480,000 kilometers of power transmission lines operating at over 35kV:

Voltage	Length, km
Over 35 kV	480,000
Among which:	
500 kV	8,000
330 kV	4,000
220 kV	77,000
110 kV	120,000

5.4 Data on grid capacities and power generated for 1991 are as follows:

Grid	Connected capacities					Power generated				
	Hydro		Thermal		Total	Hydro		Thermal		Total
	GW	%	GW	%	GW	TWh	%	TWh	%	TWh
E. China	2.5	11	21.3	89	23.8	6.8	6	112.0	94	118.8
NE China	3.9	17	19.1	83	23.0	11.1	11	91.9	89	103.0
Cen. China	8.2	37	13.8	63	22.0	34.7	34	67.2	66	102.0
N China	0.9	5	18.0	95	18.8	1.4	1	95.8	99	97.2
W China	4.4	47	5.0	53	9.4	15.7	34	30.1	66	45.8
Shandong	0.1	1	9.0	99	9.1	0.1	<1	49.3	>99	49.4
Guangdong	2.2	24	6.8	76	8.9	4.8	13	33.1	87	37.9
Sichuan	2.3	32	4.8	68	7.0	10.3	32	21.6	68	31.9
Fujian	1.6	49	1.6	51	3.2	4.7	35	8.9	65	13.6
Yunnan	1.7	57	1.3	43	2.9	7.1	61	4.5	39	11.7
Guangxi	1.4	52	1.3	48	2.8	5.4	44	6.8	56	12.1
Guizhou	0.9	42	1.3	58	2.2	3.3	32	7.0	68	10.3
W in Mongolia	0	0	1.6	100	1.6	0	0	8.7	100	8.7

5.5 Further statistics for the power sector are given in Table 5.1. These data confirm that hydroelectricity is now around 18 percent of power generated and 25 percent of installed generating capacity.

B. Energy Use

5.6 The fuels used for electricity generation are shown below, with the predominant role of coal clearly shown:

	Power generated 10^9 kWh	Total fuel 10^6 TCE	Coal 10^6 t	Coal %	Oil 10^6 t	Oil %	Gas 10^8 m^3	Effic. %
1985	318.5	123.5	156.6	84.5	13.5	15.1	3.6	30.9
1986	355.0	137.5	192.5	86.1	13.5	13.5	5.5	30.9
1987	397.3	153.8	196.2	87.1	13.4	12.3	5.7	28.4
1988	436.1	168.0	223.9	87.8	14.3	11.8	4.2	28.4
1989	466.4	180.1	274.3	89.5	17.1	10.2	9.2	28.4
1990	494.5	189.4	291.0	90.3	15.5	8.8	9.7	28.8
1991	552.8	209.8	325.9	91.4	15.0	7.7	10.6	28.7

Note: Data for units over 6 MW only. Gas includes natural gas, coke oven gas, etc.

5.7 In the near future, the contribution of nuclear power will amount to 1200 MW—two 600 MW units at the Qingshan nuclear plant, the first of which began operating in 1993.

C. Energy Efficiency

5.8 The average coal consumption of thermal power generation for the country was 427 gCE/kWh in 1991 and 420 in 1992. The efficiency of different types and sizes of equipment can vary widely. For example, data for large units in 1990 are as follows:

Size MW	Design	Coal consumption (gCE/kWh) Best	Average	Worst
100	388-390	390	418	460
125	355-358	364	392	474
200	345-360	373	394	491
300	338-344	357	362	390
600	320	-	358	-

D. Energy Efficiency Trends

5.9 The gradual and steady reduction in coal consumption for electricity generation is shown in Table 5.1.

Table 5.1: POWER SECTOR INDICATORS SINCE 1985

	1985	1986	1987	1988	1989	1990	1991	1992
Capacity, GW	87.1	93.8	102.9	115.5	126.6	137.9	151.5	166.5
inc hydro, GW	26.4	27.5	30.2	32.7	34.6	36.1	37.9	40.7
Generation TWh	410.7	449.6	497.3	545.1	584.7	621.3	677.6	754.2
inc hydro Twh	92.4	94.5	100.2	109.2	118.4	126.4	125.1	131.5
Coal rate (net) gCE/kWh	431	432	432	431	432	427	424	420
Coal rate (gross) gCE/kWh	398	398	397	397	397	392	390	386
Plant internal use								
average %	6.42	6.54	6.67	6.69	6.81	6.90	6.94	7.00
hydro	0.28	0.28	0.31	0.34	0.30	0.30	0.32	0.37
thermal	7.78	7.83	7.87	7.94	8.12	8.22	8.13	8.08
Line losses %	8.18	8.15	8.48	8.18	8.18	8.06	8.15	8.23
Utilization hours								
average	5,308	5,388	5,392	5,313	5,171	5,036	5,020	5,029
hydro	3,853	3,982	3,771	3,710	3,691	3,800	3,675	3,567
thermal	5,893	5,974	6,011	5,907	5,716	5,413	5,451	5,462
Per capita generation kWh/person	246	-	-	495	519	543	585	
Electricity as % of energy demand	18.4	22.1	22.9	23.3	24.0	25.0	26.0	

5.10 Some typical measures adopted in recent years to improve power plant efficiency are illustrated in Table 5.2. This lists 11 items and the costs and associated benefits. In most cases, the payback periods are under two years.

E. POTENTIAL FOR IMPROVEMENT

Generating Plant Mix

5.11 There are three main areas for reducing the coal consumption in the power sector—achieving a better mix of generating plants through increased exploitation

Table 5.2: ENERGY CONSERVATION MEASURES

No	Projects	(Y 100 m)	Coal equiv-alent (10 Kt)	Raw coal (10 Kt)	Elec-tricity (100 GWh)	Oil (10 Kt)	No	Technical innova-tion projects	Energy saving value (Y 100m)	Investment for unit energy saving (TCE)	Return period
1	Cogeneration (supply)	70	950	1,330	-	-	1	Cogeneration (supply)	14.25	737	4.91
2	New Type of Burner for Coal Powder Boiler	1.35	139	174	-	10.8	2	New Type of Burner for Coal Powder Boiler	2.9	97	0.47
3	Boiler Sealing for Heat Protection	2.4	85	119	-	-	3	Boiler Sealing for Heat Protection Water Pumper Speed Adjusting	1.28	282	1.88
4	Water Pumper Speed Adjusting	10	120	-	30	-	4	Water Pumper Speed Adjusting	7.5	833	1.33
5	Comprehensive Innovation for Unit of 0.2 MkW	15	220	308	-	-	5	Comprehensive Innovation for Unit of 0.2 MkW	3.3	682	4.55
6	Washing Steam Condenser by Rubble Ball	0.5	160	224	-	-	6	Washing Steam Condenser by Rubble Ball	2.4	31	0.21
7	Motor Innovation of Magnetic Slot	0.08	15.2	-	3.8	-	7	Motor Innovation of Magnetic Slot	0.95	52.6	0.084
8	Surplus Heat Recycling of Pipe Heat Exchanging	8.2	403	465	17.79	-	8	Surplus Heat Recycling of Pipe Heat Exchanging	9.46	230	0.87
9	Microcomputer Online Analysis for Energy Loss	4	350	490	-	-	9	Microcomputer Online Analysis for Energy Loss	5.25	114	0.76
10	Improving for Nonpower Compensation	12	80	-	20	-	10	Improving for Nonpower Compensation	5	1,500	2.4
11	Innovation on Electricity Distribution of Urban Area	22.8	348	-	87	-	11	Innovation on Electricity Distribution of Urban Area	21.75	625	1.05
	Total	146.33	2,870.2	3,950	158.59	10.8			74.04	782	1.94

Note: (1) Thermal supply is not included in thermal power cogeneration.
(2) Energy prices apply the shadow price: Y 150/TCE, Y 0.25 /kWh, Y 930/t. Investments are calculated with fixed prices.
(3) The investments and energy saving are forecasted based on the average results of the complete projects.

of hydroelectric resources and cogeneration systems, reduced losses in transmission and distribution, and improved efficiency of power plants.

5.12 The potential for further exploitation of hydroelectricity resources is substantial. It is estimated that 380,000 MW could be utilized, while the present installed capacity is only about 40,700 MW (10.7 percent of exploitable resources). Most of the hydroelectric resources are found in the west of the country, such as the upper and middle reaches of the Yellow River, the upper reaches of the Yangtze River, the Hongshuihe and Lanchangjian Rivers. These would all represent large hydroelectric projects, in addition to which there are opportunities for developing small and medium size hydroelectric plants on smaller rivers in the western regions.

5.13 With respect to thermal units, the large proportion of small and low/medium pressure steam plants—about 30 percent—will be reduced as the older and least efficient ones are shut down and as new large units are brought on line. Cogeneration systems, accounting for 9 percent in 1990, will increase in importance: it is expected that 10,000 MW will be added by 2000, resulting in the contribution of cogeneration rising to 12 percent. Both these actions will lead to an improvement in the efficiency of electricity generation and a reduction in the coal consumption rate of say 60 gCE/kWh (to about 370 gCE/kWh).

Reduction of Line Losses

5.14 Efforts can be made to decrease the losses now being incurred in transmitting and distributing electricity. Line losses are about 8.2 percent currently for long distance transmission, excluding local distribution networks. In 1989, a study of five major regions in the north and northeast of China gave the following results:

Main grids	> 220 kV	2-4% loss
Local urban grids	< 110 kV	3-6%
Rural grids	< 110 kV	7-9%
Rural grids, low voltage		12-20%
Industrial user networks		3-8%

5.15 The main sources of losses are:

(a) High loads are put onto old distribution systems.

(b) Expanded power generation facilities have not been accompanied by increased distribution systems.

(c) Power factor compensation is often inadequate, leading to high line losses.

(d) Networks have little or no spare capacity and thus distribution management is inflexible; transmission distances are often long but there are no alternative routings.

(e) Recent changes in electricity demand patterns—such as increased urban electricity consumption—have not been mirrored by increased distribution capacity.

To reduce losses, old and overloaded systems are being replaced, although this is a slow and costly undertaking. Replacement takes into account both increased loads and safety considerations. Reduction of the line losses by 1 percent is estimated to be equivalent to saving 6 billion kWh or 2.2 million TCE per year.

Electricity Generation

5.16 Finally, improving the efficiency of electricity generation is being carried out. In 1991, the generation of electricity consumed 326 million tons of coal or 22.4 percent of national primary energy demand: it is expected that this could rise to one third of total coal production by 2000. Improving generating efficiency could therefore make a major contribution both to reducing greenhouse gas emissions and to alleviating coal supply and transportation problems.

5.17 The present levels of coal consumption are significantly higher than in developed countries:

gCE per kWh	1980	1985	1987	1990	1991
China	448	431	432	427	424
USA	378	377	351	-	-
UK	383	358	358	-	-
Former Soviet Union	328	327	325	-	
Japan	338	327	325	-	-
Germany	340	327	321	-	-

5.18 From the present level of 427 gCE/kWh, it is expected that consumption can be reduced by about 60 gCE/kWh to 360 gCE/kWh by 2000 by measures such as the following:

(a) Ensure new generating capacity is efficient. In the next ten years or so, 100,000 MW of new capacity will need to be added to the Chinese power system. Units with capacities over 125 MW are expected to reach over 80 percent by 2000. For new coal fired condensing units of 300 MW and above, energy consumption should be under 330 gCE/kWh. For cogeneration plants, this should be 270-280 gCE/kWh. Efforts will be made to limit the construction of new medium and small size steam condensing power plants. The contribution of new units is equivalent to a reduction in energy use of about 24 gCE/kWh by 2000.

(b) Rehabilitation of old plants. Existing low and medium pressure steam turbine generating plant often have high coal consumptions. The average is about 600 gCE/kWh and some operate at 1 kgCE/kWh. These inefficient units are rebuilt to modern specifications or shut down. It is important that old equipment is not sold to other plants where it can be recommissioned later. By 1995, about 1600 MW of these units will remain in operation in remote regions of China but about 5500 MW will be replaced or reconstructed, reducing the national coal rate by over 6 gCE/kWh. By 2000, a further 10,500 MW will be reconstructed and 2,500 MW shut down, and new capacity will be provided by large high efficiency plants, reducing coal use by about 15 gCE/kWh.

(c) Improved operation of existing large plants. The design energy consumptions for new plants are often 10 percent or more higher than developed countries. In many cases, design efficiencies are not reached for a variety of reasons, such as:

(i) Boiler feedwater temperatures 30°C or more below design.

(ii) Vacuum levels in condensing equipment are not adequate.

(iii) Stack gas exhaust temperatures are high.

(iv) Excess combustion air is much higher than design rates.

(v) Plants serving the peak loads are not able to meet demand and other units are brought on line for short periods. These plants are run at low loads and low efficiency at other times.

(vi) Poor maintenance leads to lower reliability and forced outages: unplanned breakdowns cause high coal consumption through excessive start ups and shutdowns.

Through technical renovation, it is expected that coal consumption will be reduced by 2000 by about 15-20 gCE/kWh and a further 5-10 gCE/kWh by 2010. Typical consumptions for different units are thus expected to be approximately as follows:

Size, MW	1995	2000	2010
500-600	335-350	325	320
250-350	345-350	325	320
200-210	375-385	365	355
125	370-400	390	380
100-110	410-415	390	380
50 and below			
HP steam	430-440	420-430	-
LP/MP steam	580-610	560-590	-

(d) Increased adoption of cogeneration. By the year 2000, 7,000 MW of cogeneration capacity are planned. These are much more efficient suppliers of both heat and electricity, giving an equivalent coal consumption rate of say 280 gCE/kWh on the basis of sharing the energy input between the two products.

(e) Reduced in-plant use of electricity. The consumption of electricity within the generating plant itself is generally about 8 percent of the generated power. Some typical data are:

Size	Own use of electricity %		
	High	Average	Low
125 MW	10.2	8.0	5.9
200 MW	10.8	8.2	5.1
300 MW	6.8	5.3	4.3

In the smallest plants, values of 12 percent are not unknown. High consumption can be due to operating inefficient machinery such as water pumps, fans and conveyors, some of which are poorly sized or are based on old and outdated technology. There is little use of variable speed motors on combustion air fans, for example, so that these are operated at full rate all the time, regardless of the actual need for air. Air rates may be adjusted in some cases by using dampers on the fan suction, reducing the air flow and improving combustion conditions, but still maintaining the high electrical load.

5.19 Other auxiliary machines such as coal grinding equipment are simply high energy consumers compared with the type of equipment operated in developed countries. Replacement of outdated auxiliary machines by modern equipment will therefore contribute to improving the efficiency of the power plants themselves. Efforts are being made, especially in the larger plants, to adopt better designs, with experience showing that payback periods are usually well below two years.

F. Projected Outputs

5.20 According to existing plans, the forecast electricity output in 2000 is 1,350 billion kWh. This may be broken down as follows:

	2000		2010	
Source	10^9 kWh	%	10^9 kWh	%
Nuclear	19.8	1.5	35.2	1.8
Thermal	994.4	73.6	1,460.4	73.0
Hydro	334.9	24.8	500.0	25.0
Renewables	0.9	0.1	4.4	0.2
Total	1,350.0	100.0	2,000.0	100.0

6. AGRICULTURE

A. Sector Profile

6.1 The agricultural sector includes farming, fishing, animal husbandry, forestry (not including lumber industry), and water management. Although its share in GNP has been continuously declining, agriculture is still the second largest economic sector in China. Agriculture's share of GNP was 24 percent in 1990, compared with its 30 percent share in 1980.

6.2 China is the largest grain, cotton, and meat producer. Outputs of other major agricultural products such as peanut and soybean are also high. There was 95.65 million hectare (ha) cultivated land as of 1991, including 47.82 million ha irrigated land. Tractors plough about 52 percent of the cultivated land and diesel and electric pumps are applied to about 58 percent of the irrigated land. The land area that is under fully mechanized farming is small, probably around 10 percent of the total cultivated land. Most farming work in China is still done by human and animal power.

6.3 As of 1990, the total power of agricultural machinery was 287 GW, up from 150 GW in 1980. Tractors accounted for the largest share, with a total power of 90 GW. Small tractors (with an average unit power of 8.9 kW, or about 10 horsepower) provided 69 percent of the total tractor power. Irrigation pumps are the second largest group, with a total power of 71 GW, of which 53 percent was electric. Trucks used in agriculture had a total power of 46 GW (with average unit power of about 75.6 kW, or about 85 hp), motorized boats (including fishing boats) had total power of 7 GW, and the remaining 73 GW was unspecified. Table 6.1 details the stock of major energy-using equipment in the agricultural sector.

B. Energy Use

6.4 Due to the fact that China's agriculture continues to be very labor intensive, direct energy use in agricultural production remains small, accounting for about 5 percent of total commercial energy use in China. Energy consumption in agriculture was 48.5 MTCE in 1990, including 20.7 Mt coal, 8.8 Mt diesel, 1.5 Mt gasoline, and 42.7 TWh electricity. It is uncommon that China's agriculture consumes a large amount of coal which is supposedly used for drying products and cooking animal feed. Some accounting procedures which may have included coal consumption of small village enterprises probably helped inflating the real agricultural coal use figure.

6.5 About one third of the country's total diesel supply is distributed to the rural areas. While much of this fuel is used for farming activities like ploughing and irrigation,

Table 6.1: STOCK OF AGRICULTURAL MACHINERY, 1980-90 (GW)

Year	Large & medium tractors	Small & walking tractors	Boat tractors /a	Rice trans planters	Drainage and irrigation motors: Diesel	Electric	Other	Subtotal	Trucks	Motor-ized fishing boats	Motor-driven sprayers	Balance/ other /b	Total
1980 (c)	24.02	16.38	0.58	0.21	27.57	20.35	7.74	55.66	9.09	2.62	0.54	40.40	149.50
1981 (c)	25.59	17.85	0.62	0.16	27.12	20.81	7.99	55.92	11.75	2.97	0.59	43.52	158.97
1982 (c)	26.49	20.16	0.55	0.12	26.92	29.75	0.52	57.19	14.08	3.27	0.62	45.97	168.45
1983 (c)	27.46	24.25	0.48	0.07	27.41	30.66	0.46	58.53	19.11	3.31	0.67	48.85	182.73
1984 (c)	27.57	29.27	0.39	0.05	26.54	31.59	0.44	58.57	24.97	3.40	0.64	52.85	197.68
1985 (c)	27.82	34.14	0.32	0.03	26.03	31.95	0.36	58.35	31.18	3.72	0.57	55.90	212.03
1986	28.07	40.03	0.30	0.03	26.90	32.91	0.63	60.44	35.81	4.24	0.53	60.05	229.50
1987	28.76	47.13	0.28	0.04	28.18	33.97	0.43	62.58	39.66	4.86	0.53	64.53	248.36
1988	28.96	53.19	0.29	0.04	29.98	35.17	0.53	65.68	43.25	5.45	0.60	68.29	265.75
1989	28.14	58.48	0.25	0.04	32.07	36.07	0.39	68.53	46.34	6.09	0.61	72.19	280.67
1990	27.46	62.31	0.26	0.05	33.49	37.49	0.32	71.29	46.21	6.96	0.75	71.79	287.08

/c Values in these rows (except for irrigation motor subtotals, boats, and totals, which are given in watts in the Energy Statistical Yearbook) were calculated using a factor of 1 kW = 1.341 hp, derived from figures for the same year given in horsepower in the Statistical Yearbook of China and figures given in watts in the Energy Statistical Yearbook of China, 1989.

/b "Other" includes pumps, sprinkler machines, combine harvesters, motor-driven harvesters, motor-driven threshers, seed selecting machines, grain drying machines, rice and wheat mills, cotton-ginning mills, oil presses, fodder grinders and forage grass harvesters. This column also indicates discrepancies in reported values for categories and totals.

/a "Boat tractors" are used in rice cultivation.

Source: *China Energy Statistical Yearbook, 1989*; *Statistical Yearbook of China*, various years.

a significant amount is also used by tractors providing transport. Transportation is an important function of tractors in rural China, and this fuel use is accounted for in the agricultural sector.

6.6 It was estimated that about 25 percent of agricultural diesel use was used for irrigation in the mid 1980s and about 40 percent of agricultural electricity was used for irrigation. Figures for today may not have changed significantly.

6.7 While total agricultural machinery power grew at an average annual rate of 7 percent from 1980 to 1990. Diesel and electricity uses in this sector grew more slowly at less than 2 percent and 5 percent per annum, respectively. Diesel use changed little throughout most of this period. This may be attributed in part to increased energy efficiency, but it is more likely due to machinery left idle because of chronic fuel shortages.

6.8 Because of the low level of mechanization, energy input per unit agricultural output is lower in China than in industrialized countries. For example, the diesel/land ratio for grain production was 41 liter/ha for China and 51 liter/ha in the US in the mid-1980s. The electricity/land ratio for grain production was 126 kWh/ha in China and 236 kWh/ha in the US. The gain of production efficiency from mechanization is great. The labor productivity of American grain production is more than 100 times higher than that of China.

Table 6.2: AGRICULTURAL ENERGY USE, 1980-90

	Coal (Mt)	Diesel (Mt)	Gasoline (Mt)	Electricity (TWh)	Total
1980	15.50	7.49	0.53	27.00	34.71
1981	15.69	7.05	0.58	28.16	34.59
1982	17.14	6.54	0.61	28.64	35.02
1983	18.35	6.65	0.72	28.64	36.08
1984	20.18	7.05	0.89	28.84	38.44
1985	22.08	6.29	1.22	31.74	40.45
1980	22.74	6.71	1.42	32.19	42.38
1987	22.7	17.30	1.46	35.96	44.72
1988	23.55	7.67	1.54	37.89	47.09
1989	21.59	8.26	1.34	41.05	47.42
1990	20.74	8.82	1.46	42.68	48.52

Note: Total energy use in the table includes a small amount (less than 2%) other energy sources such as coke and kerosene.

Source: *China Energy Statistical Yearbook, 1989 and 1991.*

6.9 While China's agriculture presently requires less direct energy inputs compared to its Western counterparts, its demand for chemical fertilizers is comparable. Chemical fertilizer use has more than doubled, while grain production has increased little since the late 1970s. High demand for fertilizer will require more energy inputs in the chemical industrial sector. Another related issue is the burning of crop residues for cooking and space heating in the rural area. Additional fertilizer input will be needed to replace nitrogen that would probably have otherwise returned to the soil.

6.10 As more and more farmers leave the fields, switching to nonagricultural occupations and often migrating to cities, energy-using equipment will be substituted for labor and the energy intensity of agriculture will increase. Increasing use of chemical fertilizers and pesticides has relieved Chinese farmers from the intensive labor requirements of organic farming, but has increased the indirect energy intensity of farming.

C. ENERGY EFFICIENCY

6.11 Despite recent improvements, energy inefficiency in agricultural machinery is still widespread. Two cases are examined here.

6.12 Irrigation. In practice, the efficiency of irrigation pumps is 20 percent below their designed performance and 30 percent below the efficiency of their modern foreign counterparts. Four contributing factors have been identified: (a) blind drilling, without careful consideration of site groundwater reserves, has contributed to a 50 percent decrease of average irrigated area per unit pump power nationwide since the 1970s (depletion of ground water may also have contributed to this problem); (b) poor ditch and canal quality allows for seepage and decreases water delivered per unit energy input into irrigation; (c) pumps are often operated at partial load because of poor matching of pump lift with required lift, which impairs efficiency. For example, 60 percent of the irrigation pumps used in Jilin province were mainly used for water lifting below their designed lift heights; and (d) like much of other Chinese-made machinery, pump design and manufacturing technologies are backward compared to international standards. Obsolete pumps are still widely used.

6.13 **Tractors.** There two main groups of tractors presently operating in China. The fist group consists of models of 1950s Soviet design. Their fuel intensity is 10-20 grams of diesel per horsepower-hour (g/hp-hr) higher than that of their modern counterparts. The second group consists of domestic designed models based on 1960s technologies. Their fuel consumption is 5-10 g/hp-hr higher than that of their modern counterparts. In 1984, the average tractor fuel intensity was 195 g/hp-hr which was about 10 percent higher than that in industrialized countries. Poor maintenance also contributes to further worsening of tractor fuel economy.

D. Potential for Improvement

6.14 Energy management is commonly weak in agricultural production because of the lack of skills and commitment. Energy shortages in agriculture may not cause as much attention as in the industrial sector because ample manpower can always be used as the substitution. Since current agricultural production does not require much energy input the lure of energy savings is small. The government's attention in the rural area is also preoccupied by rural household energy use which is certainly a more serious issue to contend with. In addition, agricultural energy demand has significant seasonal variation. Ad hoc supply measures are adopted and are often effective for relieving the fuel and power shortage problems. Nonetheless, energy efficiency improvement deserves consideration in the nationwide energy conservation plan since agricultural electricity and diesel uses are by no means small quantities.

6.15 The improvement of agricultural energy use efficiency largely depends on the improvement of efficiency of energy-using equipment and in the ways they are operated. The former factor need to be addressed through proper production policies for the agricultural machinery manufacturing industry. Introducing modern technologies represent about 10 percent increase in tractor fuel economy and similar scale improvement of pump efficiency. Training of machine operators and routine maintenance help to prevent wasting energy in actual operation. A case study indicates that by investing in maintenance, significant amount of tractor diesel use can be saved. The cost for such kind of investment (mostly spent on purchasing equipment) is about Y 32/TCE, a very cost-effective figure.

E. Energy Use and Efficiency Trends

6.16 The mechanization of farm work, the expansion of ocean fishery, and the industrialization of animal husbandry all demand for more energy. Rural electrification is likely to cause the switch from diesel-driven pumps to electric pumps in most irrigation activities. The increasing availability of gasoline or diesel-driven light trucks may eventually put an end to the use of tractors for rural transportation. The increased mechanization of farm work will increase diesel demand. Deeper and faster processing of farm products will increase electricity as well as diesel demand. Increasing activity in ocean fishery also increases diesel demand. It is unlikely that coal consumption will increase significantly because its applications in agriculture are very limited.

6.17 The trend of physical energy intensity (energy use per ton of product) in the agricultural sector is very much decided by the extent of energy efficiency improvement and productivity growth because intensified machine use and irrigation tend to increase overall energy consumption. It is often true that the value-added energy intensity will decrease because of escalating production costs and the appreciation of farm land and other factors.

6.18 Agriculture is not an important direct energy user and it will never be one from the experience in the US. Share of agricultural energy use in total energy consumption is expected to become even smaller than current 5 percent. The absolute energy consumption of agriculture, however, will grow until reaching saturation.

7. TRANSPORTATION SECTOR

7.1 The transport sector has been divided into three parts for the purposes of the Greenhouse Gas Study—rail, road and water transport. Transport by air has not been included. Water and rail transport are particularly important for freight movements, representing 49.5 and 46.1 percent respectively of the national traffic in 1990, compared with 1.7 percent for road and 2.7 percent for all other freight traffic.

A. RAIL

Subsector Characteristics

7.2 The first rail line was built in 1,876 and the system expanded slowly to about 21,000 km of line by 1949. However, the standard of the lines and equipment remained low and only about half these lines were operable. In recent times, priority has been given to upgrading and expanding the rail network, so that the total length reached 57,802 km by the end of 1990, excluding special purpose lines:

Track under central government authority	53378 km
of which: Double track	13,024
Electrified	6,941
Track under local governments	4,424
Total track length	57,802

7.3 With the exception of the Tibet Autonomous Region, every province, municipality and autonomous region has been linked by rail. In 1990, the rail system was responsible for 53.5 percent of national passenger traffic and 71.3 percent of freight movement.

7.4 The rail subsector is divided into three functional activities under the Ministry of Railways: transportation, industry and engineering. These are supported by scientific and technological educational institutions. The Ministry is thus responsible for organizing and managing rail transportation throughout China, for operating factories to make locomotives, rolling stock and associated equipment and materials, and for design and construction of railway lines and related facilities.

7.5 With respect to transportation, there are 12 bureaux to operate different parts of the system. The industrial activities are undertaken by the General Locomotive and Rolling Stock Corporation, the General Communication and Signal Corporation, and the General Goods and Material Supply Corporation, under the responsibility of the Ministry. For construction, there are the General Engineering Corporation and the General Construction Corporation. Under the control of the respective Corporations, there are many major facilities such as the following:

Type of facility	Number
Engineering bureau	19
Locomotive and rolling stock works	35
Communications and signals factories	10
Bridge factories	8
Sleeper factories	2
Engineering machinery factories	2
Wood preservative factories	9
Special equipment and tool factories	3
Offices for goods and materials supply	9
Survey and design institutes	5

Activities in 1990 included the following:

Industrial production	
Locomotives	655
Passenger coaches	1,866
Rolling stock/wagons	18,597
Construction of track, km	
New track in operation	128
Doubled lines	355
Electrified lines	567

With respect to freight traffic, the rail system has been averaging an annual increase of about 4.5 percent per year since 1985:

1985 1,496.6 (10^9 ton-km)
1990 1,928.9

7.6 The inventory of locomotives reached over 13,000 by the end of 1990, an increase of 15.4 percent from the end of 1985: with respect to the total of diesel and electric locomotives, this reached 53.8 percent of the inventory, up 19 percent from 1985. Figures for the end of 1990 are as follows:

Type of locomotive	Number	Percent
Steam	6,279	46.2
Diesel	5,680	41.8
Electric	1,633	12.0
Total	13,592	

It is estimated that the proportion of work done by diesel and electric locomotives has been raised from 39 percent in 1985 to 71 percent in 1990.

Energy Use

7.7 Energy use may be divided into the three categories mentioned: transportation, industry and engineering. The rail subsector energy consumption amounts to about 2.5 percent of the national energy demand. In 1990, consumption was as follows:

	Coal (10^6 t)	Diesel oil (10^6 t)	Electricity (10^9 kWh)	Total (10^6 TCE)	
Transport					
Locomotives	13.97	2.70	4.10	16.21	(68.0%)
Non loco.	-	-	-	5.01	
Subtotal				21.22	(89.0%)
Industry	-	-	-	1.78	(7.5%)
Engineering	-	-	-	0.85	(3.6%)
Total	20.83	3.01	7.13	23.85	(100.0%)

For the various types of locomotive, it can be seen that coal still provides almost 70 percent of the energy used:

Fuel	Quantity	10^6 TCE	Percent
Coal	13.97 (tons)	11.05	68.0
Diesel	2.70 (tons)	3.66	22.5
Electricity	4.1 (10^9 kWh)	1.53	9.4

7.8 Energy costs represent about 19 percent of total running costs. The energy costs per million ton-km are estimated as Y 1,523 for steam, Y 2,008 for diesel and Y 1,357 for electric locomotives.

Energy Efficiency

7.9 The overall energy consumption for locomotives was equivalent to 11.9 kgCE per 1000 ton-km in 1985 and fell to 8.4 kgCE per 1000 ton-km in 1990, a decrease of 5.8 percent per year, reflected in a drop in energy consumption from 17.9 million TCE in 1985 to 16.2 million TCE in 1990.

7.10 The current efficiency of locomotives is reported as follows:

Steam	6.1%
Diesel	19.0%
Electricity	20.8%

Energy Efficiency Trends

7.11 The following data covering the period of the Seventh Five Year Plan (1986-1990) shows the trends to greater efficiency:

	1985	Plan period 1986-90		1990
<u>Transportation</u>				
Activity				
10^9 t-km	1,496.6	+4.5%/yr		1,928.9
Loco. energy use				
10^6 TCE	17.9	-1.8%/yr		16.2
kgCE/t-km	11.9	-5.3%/yr		8.4
Output value				
Y 10^6 per year		+424		
percent per year		+9.8%/yr		
TCE/Y 10,000		-0.28	(-7.1%/yr)	
<u>Construction</u>				
Output value				
Y 10^6 per year		+416		
percent		+9.8%/yr		
Energy consumption				
TCE/year		-26,200		
percent		-2.6%/yr		
TCE/Y 10,000		-0.28	(-11.3%/yr)	

7.12 Savings in energy consumption continue to be made although savings are becoming more difficult and costly to achieve. For example, the energy saving in 1985 over the previous year was 9.1 percent while the corresponding figure for 1990 was 5.3 percent.

7.13 Energy efficiency has been improved through a number of measures, such as:

(a) Campaigns to improve energy awareness of staff;

(b) Rules and regulations to promote energy saving;

(c) Introduction of improved technology;

(d) Replacement of outdated and inefficient technology;

(e) Replacement of steam locomotives by diesel and electric locomotives, with the emphasis on high horsepower machines;

(f) In industrial plants associated with railways, funds have been allocated to reforming boilers, electric arc furnaces and kilns;

(g) Application of energy saving techniques on locomotives, e.g., improved wheel lubrication; and

(h) Increased use of computerized equipment for controlling transformer systems, power factor correction, temperature and heat supply monitoring.

Potential for Improvement

7.14 A major factor which will contribute to energy efficiency is improved management of operations. For example, it has been estimated that 100,000 TCE could be saved each year if stoppage of locomotives outside stations could be eliminated and stop-start operation minimized. Optimizing train weights and running speeds will also help save energy, as will maximizing the use of diesel and electric traction.

7.15 Technological changes will lead to higher energy efficiency. These include improved AC/DC driving systems, and continuing replacement of inefficient equipment in factories.

B. HIGHWAY TRANSPORTATION

Subsector Characteristics

7.16 Highway transportation is a fast growing segment of China's transportation sector. The average growth rates of road freight movement and road passenger traffic registered 16 and 14 percent per annum respectively from 1980 to 1990. In 1990, road freight movement reached 335.81 billion ton-km, accounting for 12.8 percent of total freight movement, and road passenger traffic reached 262.03 billion passenger-km, accounting for 46.6 percent of total passenger traffic (Table 7.1).

7.17 Current per capita road freight movement and passenger traffic are about 300 ton-km and 240 passenger-km, respectively. They are very low compared with about 4,000 ton-km and 10,000 passenger-km per capita in the US, indicating great potential for growth.

7.18 The stock of motor vehicles (trucks, buses, vans and cars) has been increasing at 12 percent per year since 1980. There were over 5.5 million freight and passenger vehicles in 1990, with each category sharing 66.8 percent and 29.4 percent,

Table 7.1: HIGHWAY FREIGHT AND PASSENGER TRAFFIC, 1980-90

	Freight (Bn-t-km)	% of Total	Passenger (Bn-pas-km)	% of Total
1980	76.4	6.4%	72.95	32.0%
1981	78.0	6.4%	83.90	33.6%
1982	94.9	7.3%	96.39	35.1%
1983	108.4	7.7%	110.56	35.7%
1984	153.6	9.8%	133.69	36.9%
1985	169.3	9.3%	172.49	38.9%
1986	211.8	10.5%	198.17	40.5%
1987	266.0	12.0%	219.04	40.5%
1988	322.0	13.5%	252.82	40.7%
1989	337.5	13.2%	266.21	50.0%
1990	335.8	12.8%	262.03	46.6%

Source: *Statistical of China Yearbook, 1992.*

respectively. The number of vehicles in China remains low at about 5/1,000-person. More details about the motor vehicle stock are depicted in Table 7.2.

7.19 In addition, there were over 4.2 million motorcycles and about 4.6 million tractors running on China's roads in 1990. Current stock of cars is not reported in any official statistics. Judging from the increase of small passenger vehicles, the number of cars must have been increasing rapidly, too. The stock of small passenger vehicles grew over 6 times from 1980 to 1991. Their share of China's total motor vehicle stock increased from 13 percent in 1980 to 25 percent in 1991.

7.20 Current truck fleet consists of mostly domestic-made and gasoline-driven Jiefang and Dongfeng brands with 5 ton payload. Popular domestic-made diesel-driven trucks have 10 ton payload. Gasoline-driven vehicles account for over 80 percent current truck and bus stock.

7.21 The majority of registered motor vehicles are so-called own-account vehicles owned by nontransport enterprises, work units, collective or private entities. In 1991, only 316 thousand trucks and buses belonged to state-owned professional transportation enterprises. Food, trade and merchandise enterprises also operate a sizable number of business-oriented trucks. Even though the state-owned professional vehicles only accounted for 5.2 percent of total motor vehicle fleet, they contributed to 72 and 11 percent of total road passenger traffic and freight movement respectively, indicating the important role of professional companies.

Table 7.2: MOTOR VEHICLE STOCK IN THOUSANDS, 1980-90

	Large trucks	Small trucks	Buses	Vans & cars	Total
1980	1,257.6	41.4	113.0	237.8	1,782.9
1981	1,374.1	66.8	130.4	275.3	1,991.4
1982	1,480.6	86.9	145.6	296.2	2,157.5
1983	1,576.7	117.7	161.3	316.5	2,326.3
1984	1,695.6	188.1	182.3	380.5	2,604.1
1985	-	-	-	-	3,211.2
1986	-	-	-	-	3,619.5
1987	2,191.9	620.3	273.6	841.0	4,080.7
1988	2,370.1	718.8	299.4	1,004.4	4,643.9
1989	-	-	311.9	1,152.4	5,113.2
1990	2,604.9	1,079.9	333.0	1,288.9	5,513.6

Note: Total figures also include specialty vehicles. Large trucks have an average payload of about 5 tons. Small trucks have an average payload of 1.7 tons. Buses have an average of 40 seats. Vans and cars are classified as small passenger vehicles in official statistics and have an average of 8 seats.

Source: *Statistical of China Yearbook 1992.*

7.22 There was total 1.04 million km of roads in 1991, compared with 88.83 million km in 1980. Road quality is poor. First class highway (15-m wide with speed limit of 80-100 km/hr) only accounted for 0.33 percent of total road mileage and the share of second class highway (9-m wide with speed limit of 40-80 km/hr) was 4.6 percent of the total mileage of the roads. About 27 percent of the roads have asphalt or cement surfaces and the rest have stone or even dirt surface. Construction of first and second class roads has been extensive in recent years.

7.23 The efficiency of road transportation is low not only because of poor road quality but also because of the mix-up of multi transportation modes. Motor vehicles share highways with tractors, bicycles, and animal-pulled wagons (Table 7.3).

7.24 The Ministry of Transportation administrates the national roadway and waterway systems and is responsible for formulating regulations and policies of highway and water transportation, making development plans, and managing large enterprises affiliated with the ministry. Provincial transportation departments, which reports to the Ministry of Transportation, manage local roads and road transportation.

Table 7.3: ROAD TRAFFIC MIX ON HIGHWAYS (%)

	Total traffic	Motor vehicles	Tractors & others	Bicycles & animal wagons
All roads	100	48.7	34.8	16.5
State Highways	100	65.0	23.8	11.2
Provincial Highways	100	56.5	32.0	11.5
County Roads	100	42.8	39.6	17.6
Rural Roads	100	28.1	44.6	27.3

Note: Motor vehicles include trucks, buses, vans, and cars.

Energy Use

7.25 There is no official statistics of energy consumption in highway transportation. Since road vehicles in China consumes mostly gasoline and diesel (there is a small number of buses powered by electricity and natural gas), we could assume that all gasoline use is for road transportation. It is difficult to estimate diesel use in road transportation because there are quite a few applications of diesel. As indicated by data in Table 7.4, gasoline and transportation-sector diesel consumption have increased significantly in the 1980s, registering 7.4 and 8.4 percent per year from 1980 to 1990. Shortages of gasoline and diesel are widespread and leave many vehicles idling.

Energy Efficiency

7.26 In general, fuel intensity of freight transportation has been declining while that of passenger transportation has been increasing, indicating the gradual efficiency improvement in trucking and the increasing comfort (which usually offsets efficiency improvement) level in passenger transportation. Table 7.5 reveals fuel intensity trends of professional trucking and passenger transportation. Vehicles operated by nonprofessional enterprises or work units usually perform not as well.

7.27 Compared with industrialized countries, China's road transportation is poor in fuel economy and low in operation efficiency. The contributing factors to the mediocre performance of road vehicles includes:

(a) **Inefficient Engine Design.** Domestic-made trucks and buses usually have fuel efficiencies that are 10-20 percent lower than their modern foreign counterparts. Table 7.6 and Table 7.7 compares popular models of domestic-made trucks and buses with comparable foreign ones.
Unlike those of Western countries, motor vehicle manufacturers in China

Table 7.4: GASOLINE AND TRANSPORT-SECTOR DIESEL USE, 1980-90

	Gasoline (Mt)	Increase over previous year	Diesel (Mt)	Increase over previous year
1980	9.986	-	3.161	-
1981	9.401	-5.8%	3.033	-4.0%
1982	9.931	5.6%	3.308	9.1%
1983	10.949	10.3%	3.656	10.5%
1984	11.997	9.6%	3.907	6.9%
1985	13.913	16.0%	4.544	16.3%
1986	15.002	7.8%	6.808	27.8%
1987	18.094	20.6%	6.500	11.9%
1988	18.516	2.3%	6.900	6.1%
1989	20.097	8.5%	7.210	4.5%
1990	20.426	1.6%	7.094	-1.6%

Note: Transportation-sector diesel use includes railway diesel consumption and does not include diesel used by own-account trucks and buses.

Source: *China Energy Statistical Yearbook, 1991.*

do not subject to strict regulations on the fuel economy of their product. Progress in this regard is slow.

(b) Inefficient vehicle fleet structure, especially that of trucks. The share of mid payload trucks is too high, while the shares of heavy and light-duty trucks are too low. The current ratio of the number of vehicles between large (payload > = 7 ton), mid (payload 5-7 ton), and small (payload = < 4 ton) trucks is 1:6:3, while the optimal ratio is considered to be 1:2:7. Diesel trucks which run more efficiently and tow heavier load than gasoline trucks only accounted for about 18 percent of the truck fleet. In comparison, in the US, not only all heavy-duty trucks are diesel-driven but also about 70 percent of the mid payload trucks are diesel driven.

(c) Poor road quality and inadequate road capacity. High quality first class roads make up only 0.33 percent of China's total road mileage. Only 26 percent of the roads are paved. Tests have shown that motor vehicles consume 19, 23 and 40 percent more fuel respectively on second, third and forth-class highways than on first-class highway. With narrow unpaved roads been the majority plus low road density, highways in China are crowded. Transportation modes of all sorts share most of the highways. Mixed road traffic reduces transportation efficiency and fuel economy.

Table 7.5: FUEL ECONOMY OF TRANSPORTATION COMPANIES, 1980-91
(in liter/1000-ton-km)

	Gasoline trucks	Diesel trucks	Gasoline buses	Diesel buses
1980	87	62	78	66
1981	85	60	80	55
1982	82	59	79	56
1983	80	58	81	57
1984	79	57	79	56
1985	77	53	80	61
1986	76	51	81	64
1987	76	51	82	68
1988	72	48	82	64
1989	71	47	81	65
1990	71	48	87	72
1991	69	46	88	72

Note: Bus fuel intensity is converted from liter/vehicle-km.

Source: *China Energy Statistical Yearbook, 1991.*

According to the investigation of Anchin city highway management office, mixed traffic reduces vehicle speed by 18 percent compared with divided-lane traffic. A study about the Goubei highway in Liaolin province reveals that mixed traffic reduces vehicle speed by 32 percent, increases fuel consumption by 16 percent, and increases gear change five times compared with divided-lane traffic.

(d) Small share of professional road transportation and mediocre operation management. Trucks owned by enterprises or work units that have no business-oriented trucking operation contribute to about half of the total road freight movement. The payload utilization rate of these trucks is about 30 percent compared with over 60 percent for trucks operated by the professional transportation companies.

7.28 China's car fleet consists of mostly imported cars and cars assembled in joint ventures, representing technologies of early to late 1980s. The fleet fuel economy of cars operated in China are considered low because poor road condition, lack of maintenance, and low octane gasoline all reduce energy efficiency. Gasoline consumption by cars is still small compared to that by trucks and buses. Since domestic car manufacturing is still in its formative stage, regulation on fuel economy and selectively choosing eager foreign investors could have great preventive impact on future gasoline demand.

Table 7.6: COMPARISON OF TRUCK FUEL ECONOMY, SELECTED COUNTRIES

Engine type	Model	Gross weight (ton)	Payload (ton)	Horsepower	Fuel economy (liter/1,000-t-km)
Gasoline	Jiefang CA15 (China)	9.1	5.0	115	53
	Dongfeng EQ140 (China)	9.3	5.0	135	56
Diesel	Yuejing NJ131 (China)	5.7	3.0	88	55
	Huanghe JN162 (China)	17.3	10.0	210	26.5
	Mitsubishi KFK216	7.8	4.3	33.3	
	Mitsubishi KFM316	12.3	7.0	21.3	
	Benz 1217L (Germany)	14.0	8.0	192	19.3

Note: Fuel economy figures are converted from liter/1000-vehicle-km to liter/1,000-ton-km by dividing the former with payload. Actual fuel economy varies with payload utilization.

Table 7.7: COMPARISON OF BUS FUEL ECONOMY, CHINA AND JAPAN

Engine type	Model	Gross weight (ton)	Seats (person)	Horsepower	Fuel economy (liter/1,000-t-km)
Gasoline	JT662 (China)	9.3	45	135	6.0
Diesel	JT680 (China)	15.1	60	160	4.2
	Nissan KDA50T	17.5	60		3.9
	Hino RU236	16	48	320	3.5

Note: Fuel economy figures are converted from liter/1,000-vehicle-km to liter/1,000-passenger-km by dividing the former with passenger capacity. Actual fuel economy varies with seats utilization.

Potential for Improvement

7.29 Introducing modern engine designs and manufacturing technologies represents 10-20 percent increase in fuel economy over popular domestic engine models.

7.30 Increasing the share of diesel trucks in freight transportation saves fuel. On the average, diesel trucks use 20 percent less fuel per unit freight movement than gasoline trucks. This measure also calls for production adjustment of truck manufacturing industry and oil refining industry. Road conditions have to be improved to accommodate more and larger and heavier diesel trucks. Increasing the share of light-duty trucks may displace many large trucks owned by work units and make miscellaneous uses of trucks more efficient.

7.31 Promoting the development of professional trucking also help to displace underutilized own-account trucks. Fuel savings can be achieved by improved load utilization rate and better maintenance of vehicles. There is significant potential for improvement in operation efficiency of the professional trucking companies. Investment in management and skill enhancement usually have very attractive economic returns.

7.32 Increasing gasoline octane value improves fuel economy. Studies have found that increasing gasoline octane value from previous 70 to current 80 resulted in 10 percent increase in fuel economy of popular gasoline truck models. Most operating gasoline trucks have to be modified to use higher octane-value gasoline. The payback time for the adjustment ranges from 16 to 28 months. The estimated gasoline savings from this measure are about 1 Mt gasoline per year. Considering that trucks in China usually have prolonged life, this measure is considered viable.

7.33 Improving road quality would greatly increases road transportation efficiency and significantly reduces fuel use. Over 90 percent of current highways is third and lower class roads. Upgrading roads, however, calls for major investment.

7.34 Other measures that help to improve energy efficiency include more extensive use of radial tires, preventive maintenance, and driver education.

Energy Use and Efficiency Trends

7.35 Transportation has become an important constraint of China's economic development. Developing highway transportation is a major part of the integrated approach to resolve issues concerning transportation bottlenecks. Overall efficiency of transportation can be improved if the highway system could handle more of short-to-medium range movement of freight and passengers and make the railway system more available for large and long-haul activities.

7.36 Extrapolating current trends, we expect the importance of highway transportation to continue to increase. China's automotive industry has highlighted two major areas for development: heavy-duty trucks and passenger cars. Connecting major cities with superhighways is a high priority of China's planners and is encouraged by foreign investors.

7.37 Transportation activity tends to increase in tandem with the overall economic growth. With increasing trucking capacity and car ownership, large increase of gasoline and diesel consumption is expected. This development may cause large quantity of oil import if domestic supply falls short.

7.38 In freight transportation, energy efficiency is expected improve with new and better trucks replacing inefficient old trucks and with increasing fleet share of diesel-driven trucks. In passenger transportation, energy efficiency improvement may be offset by increasing comfort level (less crowded buses). The growing number of cars also reduce the overall energy efficiency of passenger transportation.

C. Water Transportation

Subsector Characteristics

7.39 Water transport is an important element of the Chinese transport system: it is used extensively for movement of bulk cargo and for long distance freight transfers. Water transport represents about 50 percent of freight movements and 90 percent of import and export cargoes are moved by sea. The entire water transport system includes shipping, ports, inland waterways, salvage and ship repair activities: this section focusses mainly on shipping and ports.

Table 7.8: Historical Data on Numbers of Motor Ships

Year	Inland	Coastal	Ocean
1980	31,450	2,000	637
1981	32,740	2,188	677
1982	33,063	2,305	733
1983	36,632	2,651	741
1984	38,678	2,720	772
1985	44,708	2,706	878
1986	46,583	2,767	894
1987	44,751	2,811	938
1988	45,259	2,666	1,037
1989	46,082	2,637	1,130
1990	46,473	2,673	1,231
1991	44,855	2,479	1,265

Total net tonnage of motor ships in 1991:

Inland: 2.20 million ton
Coastal: 6.22 million ton
Ocean: 16.33 million ton

7.40 The Ministry of Communication is the government administrative agency concerned with this part of the transport sector, responsible for water transport policies and regulations, for the development and macro-level planning of transport, and for the direct management of large-scale water transport enterprises. The Communication Bureaux of Provinces are the administrative agencies of local governments in relation to water transport and the management of local water transport enterprises. In a similar manner to the regulation, control and operation of road transport, Ministry responsibilities regarding water transport are discharged through several departments:

Table 7.9: PASSENGER TRAFFIC DATA, 1980-91

Year	Inland	Coastal	Ocean
	Historical Passenger Turnover by Ship (100 million passenger-km)		
1980	110	17	1.5
1981	110	26	1.7
1982	114	27	2.2
1983	120	31	2.4
1984	119	32	2.3
1985	133	38	2.8
1986	131	37	2.5
1987	134	41	3.4
1988	142	44	3.1
1989	131	42	3.1
1990	110	39	3.5
1991	116	42	4.1
	Historical Freight Turnover by Ship (100 million ton-km)		
1980	560	937	3,539
1981	564	942	3,643
1982	650	1,057	3,768
1983	698	1,102	3,977
1984	763	1,189	4,373
1985	827	1,419	5,328
1986	894	1,590	5,947
1987	947	1,735	6,575
1988	1,019	1,890	6,965
1989	1,021	2,244	7,688
1990	904	2,338	8,140
1991	960	2,772	8,990

(a) **Planning**—responsible for medium and long term planning and for annual plans for the water transport industry in accordance with national economic and social development, supervising implementation and ensuring state directives are met and urgent material transport needs are fulfilled.

(b) **Transportation Administration**—responsible for formulating relevant regulations; examining and approving the establishment of water transport enterprises and the opening of shipping routes for international or transprovince trade, and for promoting integrated transport systems.

(c) **Engineering administration**—responsible for formulating regulations, standards, specifications and quotas relating to the construction and maintenance of water transport facilities; examining and approving design documents for key state projects, and checking implementation of these projects; studying problems of the development and utilization of inland waterways, including locks, dams and nonnavigable waterways.

(d) **Safety**—responsible for checking the seaworthiness of vessels and vessel traffic control; supervising handling of dangerous cargoes; preventing damage caused by pollution from vessels and other environmental protection work; formulating rules and regulations related to water transport safety.

(e) **Science, Technology and Education**—responsible for organizing and implementing key research projects; administration of higher education, adult education and professional and technical training related to water transport.

To strengthen energy management, the Ministry of Communications set up an Energy Management Office whose functions include formulating energy efficiency policies, regulations and standards, and supervising their implementation. The Office also monitors energy consumption by major consuming enterprises and coordinates development of energy saving technologies. Reporting to the Office are the Energy Conservation Technology Service Center, the Energy Utilization Monitoring Center and the Energy Conservation Training Center, the latter being responsible for research and testing of energy saving technology in addition to personnel training.

7.41 Water transport may be divided into three major categories—ocean, coastal and inland. The *ocean transport* element has grown rapidly with the increasing development of foreign trade. In 1951, a joint Polish-Chinese firm was set up known as the Sino-Polish Joint Stock Shipping Company. In 1961, China began operating its own fleet under the name of the China Ocean Shipping Company (COSCO). COSCO is now the largest state-run ocean shipping fleet and owns and operates over 600 vessels totalling 15 million DWT, serving over 1100 ports in over 150 countries and regions.

7.42 By 1991, the companies authorized to conduct ocean shipping reached over 100 with 1265 ships of various types, totalling 16.33 million DWT (Table 7.18). China's fleet undertakes 87 percent of the total import and export traffic, as well as some international traffic for third countries. In 1990, freight movements was 904 billion ton-km (Table 7.19) and was 70 percent of the total freight volume for water transport departments. The average freight transport distance by sea was 8,508 km.

7.43 The Chinese mainland coastline is 18,000 km long. Coastal transport forms an important north/south corridor for delivering domestic cargoes and has played a major part in the economic development of coastal areas. Coal is transported from north to south and grain form south to north: raw materials, industrial products and people are moved by a fleet of 2,479 vessels totalling 6.6 million DWT. There are 29 major seaports, including several large modernized ports such as Dalian, Qinghuangdao, Tianjin, Shanghai and Guangzhou. There are many modern terminals for crude oil, ore, bulk grain and containers with a total of 968 berths, 296 of which can accommodate vessels of 10,000 DWT and above.

7.44 The largest ports are Shanghai and Dalian—primarily for coal, crude oil, steel, iron, timber and salt from north to south, and grain, metal ores and industrial products from south to north. Guangzhou is also important for transporting agricultural products, ores, salt and coal.

7.45 In 1990, freight movements amounted to 240 billion ton-km, about 20 percent of water transport trade (277.2 billion ton-km in 1991). The average distance for coastal shipments was almost 1,900 km. Three major companies under the Ministry of Communications—Shanghai Maritime Transport Bureau, Guangzhou MTB and Dalian Steamship Company—are responsible for 85.8 percent of coastal freight capacity and carry annually over 48 million tons of coal, 21 million tons of petroleum, 4 million tons of iron and steel, as well as over 9 million passengers. Total freight throughput in 1990 was 532.2 million tons via major coastal seaports.

7.46 There are 96 coastal shipping routes for passengers. Transport departments alone transported 25.84 passengers in 1990 out of a total of 51.33 million passengers through major ports in 1990. Table 7.19 provides historical data on passenger traffic.

7.47 Inland waterways are important in China. The main river systems include the Yangtze, Heilongjiang, Zhujiang Rivers and the Beijing-Hangzhou Grand Canal system. Motorized vessels for inland water transport number 44,855 and total 2.2 million DWT. In 1991, passenger traffic was 11.6 billion passenger-km (72 percent of the traffic of water transport departments) and freight traffic to 96 billion ton-km (8 percent of the total). The average inland freight transfer distance was 290 km in 1990 and 301 in 1991 (Table 7.13).

7.48 The Yangtze River is the most important artery for inland water transport, carrying 26 million persons and 63.45 million tons of freight in 1991. The China Changjiang River Shipping Corporation is the largest inland water transport enterprise, involved mostly in bulk cargo transport such as coal, petroleum, steel, building materials and grain, as well as passengers.

7.49 The characteristics and condition of inland waterways are important factors affecting vessel performance and fuel consumption. The gradual deterioration of waterway conditions and decrease of navigable channel lengths in the 20 years up to 1980 resulted in the proportion of freight being carried on inland waterways dropping to 7 percent and waterways to 108,500 km in that year. While the situation has improved a little, statistics for 1991 show the length of inland waterways is still only 109,700 km (Table 7.10), of which 60,336 km (55 percent) have a water depth of 1 meter or more (Table 7.11). About 5,700 km (5.2 percent) are navigable for vessels of 1,000 DWT or above and about 15,850 km (14.5 percent) for vessels of 300 DWT or above. As Table 7.12 shows, there are 1,754 inland river ports: of these, 264 (15 percent) have an annual capacity of over 500,000 tons.

Table 7.10: INLAND WATERWAY LENGTHS

Year	Total (km)	Length with 1 meter and above depth
1980	108,508	54,800
1981	108,665	54,922
1982	108,634	55,595
1983	108,904	56,177
1984	109,273	56,732
1985	109,075	57,456
1986	109,404	57,456
1987	109,829	58,165
1988	109,364	57,971
1989	109,040	58,131
1990	109,192	59,575
1991	109,703	60,336

7.50 The construction of inland waterways and ports depends mainly on investment by the government and the levy of waterway maintenance tolls. The toll is levied on the basis of 8 percent of shipping company operating incomes and totals Y 200 to Y 300 million annually. This amount, together with other investments made by the government, is not enough to improve the condition of waterways through major projects and therefore most remain in much the same condition from year to year. In 1986, the average tonnage of inland waterway vessels was 100 DWT which gives rise to relatively high costs and fuel consumption. The situation is not believed to have changed much since then.

Table 7.11: INLAND WATERWAY NAVIGATION LIMITS, 1991

Type	Navigable ship (tonnage)	Depth (m)	Length (km)
1st grade	3,000	3.5-4.0	1,378
2nd grade	2,000	3.4-3.8	162
3rd grade	1,000	2.0-2.4	4,202
4th grade	500	1.6-1.9	4,559
5th grade	300	1.3-1.6	5,553
6th grade	100	1.0-1.2	18,013
7th grade	50	0.7-1.0	13,608
Other	<50	<0.7	62,164
Total			109,427

Table 7.12: MAIN RIVER SYSTEMS AND NUMBERS OF PORTS

	Mileage (km)	Number of ports	?
Changjiang Rivers	70,340	1,168	198
Heilongjiang Rivers	5,808	40	3
Zhujiang Rivers	12,619	161	26
Jing-hang Canal	1,221	65	29
Huanghe Rivers	1,754	18	-
Total	91,742	1,452	256

Energy Use

7.51 Most of the energy consumed in water transport is in the form of diesel oil. Consumption by ships of the water transport departments was 5.71 million tons in 1991:

	Million tons	*Percent*
River vessels	0.83	15
Coastal	1.38	24
Ocean	3.50	61
Total	5.71	100

Table 7.13: AVERAGE DISTANCE FOR FREIGHT TRANSPORT (km)

Year	Inland	Coastal	Highway	Railway
1980	198	1,320	34	526
1981	189	1,323	35	544
1982	203	1,373	38	539
1983	218	1,382	42	559
1984	234	1,398	45	597
1985	248	1,560	46	636
1986	261	1,512	47	662
1987	267	1,556	49	690
1988	273	1,575	55	702
1989	294	1,682	58	707
1990	290	1,758	56	725
1991	301	1,897	55	740

Historical data for fuel consumption are given in Table 7.14.

Energy Efficiency

7.52 Table 7.15 gives historical data for fuel consumptions in the water transport subsector. In 1991, the average fuel consumption for freight movements by ship was as follows:

	kg per 1,000 ton-km	Relative traffic
River	8.15	100
Coastal	4.94	288
Ocean	3.89	936

7.53 The main factors affecting fuel consumption are the water transport infrastructure (e.g., ports and waterways), the technical performance of ships, and operations management. Most of the inland waterways in China remain in a natural state and many are unable to be used within the transport network due to blockage of the channels. Congestion in coastal ports of both vessels and cargo is a common problem due to insufficient capacity—lack of handling facilities for freight, low number of general cargo and container berths, etc.

Table 7.14: FUEL CONSUMPTION OF WATER TRANSPORT (10,000 ton)

Year	Inland	Coastal	Ocean	Total
1980	76	71	181	328
1981	72	68	178	318
1982	78	75	181	334
1983	77	76	183	336
1984	82	79	190	351
1985	82	87	242	411
1986	84	94	270	448
1987	86	96	300	482
1988	90	101	289	480
1989	92	115	323	530
1990	83	119	360	562
1991	83	138	350	571

Table 7.15: FUEL CONSUMPTION COMPARISONS FOR SHIPS (kg/1,000 ton-km)

Year	Inland	Coastal	Ocean	Average
1980	12.4	7.50	5.11	6.43
1981	11.6	7.12	4.88	6.11
1982	11.1	7.01	4.79	6.03
1983	10.2	6.81	4.59	5.74
1984	9.97	6.56	4.34	5.48
1985	9.18	6.05	4.54	4.86
1986	8.75	5.84	4.54	5.26
1987	8.47	5.47	4.56	5.15
1988	8.25	5.28	4.15	4.81
1989	8.46	5.08	4.21	4.79
1990	8.65	5.05	4.42	4.91
1991	8.15	4.94	3.89	4.46

7.54 The technical level of the vessels themselves is equivalent to international levels of the early 1980s, representing a technology gap of say 10 years. The fleet composition is typically oriented to small ships. Container and other specialist ships represent a small proportion of the tonnage: for example, about 60 percent of general cargo is containerized in developed countries and only 25 percent in China. The age of ships is also rather high. Of national fleets over 20 million DWT, China ranks 25 out of

35 for the age of its ships. The average age of ships in the ocean-going category is 15 years and the coastal fleet has 30 percent of hips over 20 years old. Older ships have poorer fuel consumptions due to the aging of engines and the deterioration of hulls by corrosion.

7.55 Ship engines have been improved throughout the world and advanced foreign diesel engines operate at about 115-gm fuel per HP hour. It is estimated that Chinese ocean-going ships use 20 gm/hp.hr more than typical foreign counterparts. Inland and local coastal ships use older technology engines using typically 175-180 gm/hp.hr.

7.56 The operating rate of ships is also lower than foreign counterparts. For example, the average operating rate for ships is about 85 percent for China. Ocean-going ships may reach 93 percent but this is still far behind foreign fleets which often reach 98 percent or 355-360 operating days per year.

Energy Efficiency Trends

7.57 In 1986, the Ministry of Communication issued "Regulations on the Management of Energy Conservation in the Transport Industry" which were "to strengthen energy management in a scientific way, to renew and renovate energy intensive equipment in a planned way, to utilize energy rationally" and utilize technological advances. The regulations include instructions for keeping proper energy consumption records and conducting routine analysis of performance.

7.58 Some results of attention to energy efficiency are as follows:

(a) Old ships have been renovated and engines replaced with a saving of up to 20 percent of fuel. Large numbers of old steam ships have been replaced.

(b) Optimization of the operation of older ships allows them to sail at lower speeds and decreased power, thus decreasing energy use by 8-10 percent.

(c) Improvements to propeller design have led to energy savings of 8-10 percent without reducing the speed of the ships.

(d) Improvements have been made to the load distribution of ships, regulating the length, depth and geometry of the ship's waterline and reducing wave resistance and friction around the ship: propulsion efficiency improves 5-20 percent.

(e) Hull roughness has been reduced by clearing rust and marine growth with underwater cleaners and coating the hull with smooth compounds to reduce friction. Results show energy savings of 5-20 percent.

(f) Adding fins and nozzles near the stern of ships to improve flow patterns can reduce fuel consumption by 6-10 percent.

(g) Improved navigation systems are being adopted to help ships make full use of favorable weather conditions (e.g., winds) and the state of the sea (e.g., currents, waves).

(h) Energy efficient ships are being tested, such as a shallow draft/wide beam bulk carrier, ships with modified stern shapes to improve water flow patterns, and sail aided motor ships. Energy savings from 8-30 percent are anticipated.

Potential for Improvement

7.59 By continuing to apply the methods and technologies listed above, further improvements are expected. In addition:

(a) The replacement of old ships by new energy efficient vessels will lead to major energy savings also, as many of the ships in the present fleet are already quite old.

(b) Larger ships should form a larger proportion of the total, and this may require upgrading of ports, handling facilities and channel depths.

(c) Further use of roll-on, roll-off transfer methods for cargo and passenger vehicles will shorten journey times and lead to more effective use of ships.

(d) The average loading capacity of inland waterway barges will be increased.

(e) The average transport distance of river vessels and increased power of tugs could reduce energy consumption by 20-40 percent.

(f) Use of containerized transport should be promoted.

Projected Activity and Energy Use

7.60 Forecasts of freight and passenger traffic have been made:

	Freight quantity 10^6 t	Freight activity 10^9 ton-km	Number of passengers 10^6	Passenger traffic 10^9 pass-km
1990	539	1,139	188	15.8
2000	956	2,240	198	18.6
2010	1,499	4,011	204	21.5
2020	2,115	5,937	208	23.7

The following energy forecasts have been estimated:

	2000	2010	2020
Freight and passenger activity (10^9 ton-km equivalent)	2,249.3	4,021.5	5,953.4
Fuel consumption (kg oil/1,000 ton-km)	4.52	4.29	4.16
Forecast diesel fuel use (10^6 tons)	10.17	17.25	24.77

8. ENERGY USE IN BUILDINGS

8.1 Energy use in buildings, namely residential and commercial buildings, is an important issue not only because huge amount of energy is involved, about one fifth of total commercial energy consumption and all of biomass consumption, but also because health hazards of current building energy use are severe and extensive. Energy conservation measures that include fuel switching, energy-efficiency equipment, and improvement of energy services would reduce future energy demand as well as the costs of health care.

A. Residential Sector

Sector Profile

8.2 In 1990, China's population was 1.14 billion. According to average household sizes in urban and rural areas, the residential sector includes about 280 households and about 70 percent of them are located in rural areas. Since the late 1970s, there have been two distinctive demographic changes that have long-term impact on residential energy demand. China's population is moving faster than ever to urban areas and households are becoming smaller. Censuses in 1982 and 1990 indicated that the share of urban population increased five percentage points and the growth rate in the number of households outpaced that of the population by a factor of two. In contrast, there was virtually no net migration of population between rural and urban areas in the 1960s and 1970s and the growth rate of households lagged behind that of population from 1953 to 1982.

8.3 Households are smaller and richer than ever before. Official statistics have shown that the average real wage per employed person increased about 1.5 times from 1978 to 1990. The actually increase of personal income may be significantly larger because bonuses and cash awards have become very important nonwage income avenues. Corresponding to the increase in personal income, per capita living expenditure (in real terms) of rural and urban residents increased 2.1 and 1.8 times respectively from 1978 to 1990. The increase of household appliances such as color TV sets and refrigerators is phenomenal (Table 8.1).

Table 8.1: STOCK OF MAJOR APPLIANCES, 1978-90
(million)

Year	Electric fans	TV sets	Electric clothes washers	Refrigerators
1978	9.20	3.04	0.01	0.09
1979	10.50	4.85	0.03	0.13
1980	13.65	9.02	0.26	0.19
1981	17.92	15.62	1.50	0.25
1982	25.91	27.61	5.90	0.44
1983	333.57	36.11	12.52	1.05
1984	43.40	47.63	19.28	1.82
1985	63.60	69.65	30.30	4.10
1986	86.05	92.14	43.33	7.27
1987	111.88	1116.01	57.62	11.81
1988	145.46	143.44	74.64	19.27
1989	173.33	165.93	87.01	25.54
1990	201.27	185.46	96.28	29.96

8.4 According to a survey conducted in 1989, there were about 3,543 million m^3 residential floor space in the urban areas, about 1,547 million m^3 of it located in the official heating zone.1/ Table 8.2 reveals more details about China's building stock.

8.5 For both urban and rural residents, the largest increase in living space was achieved since the late 1970s. Per capita floor space for urban and rural residents was about 7 and 9 m^2, respectively, in 1979 and increased to about 12 and 17 m^2 in 1989. Although rural residents generally have greater floor space, the quality of housing is usually higher in urban areas.

8.6 The urban building stock consists of mainly low-rise buildings. By the end of 1985, about 50 percent of the building stock was single-floor buildings and another 28 percent was two or three-story buildings. There was no significant change in this

1/ Traditionally, the government has divided the nation into three climate zones for selecting different heating options. Areas that have more than 90 days of below 5°C outdoor daily average temperature per year are classified as heating zone. Areas that have 60-89 such days, or areas that have more than 75 days per year during which the average daily outdoor temperature is less than 8°C are classified as transition zone. The rest of the country falls into the nonheating zone. The heating zone occupies about two thirds of China's territory and has about 50 and 40 percent of the nation's urban and rural population, respectively.

Table 8.2: ESTIMATE OF RESIDENTIAL AND COMMERCIAL BUILDING STOCK, 1989

	Urban /a population (mln)	Rural /a population (mln)	Comm. /b buildings (mln m²)	Urban res. buildings (mln m²) /b	Rural res. buildings (mln m²) /b	All bldgs floor area (mln m²)
Heating zone	146.5	338.5	458	1,547	5,755	7,760
Transition zone	87.7	280.2	330	1,176	4,763	6,269
Nonheating zone	61.2	212.9	231	821	3,619	4,671
Total	295.4	831.6	1,019	3,544	14,137	18,700

/a Population distribution derived from the official 10% sample data (SYC 1991).

/b The total figures and the heating zone figures for urban buildings are from Tu and Wang (1991). Transition zone and nonheating zone figures are derived from the population ratio. Rural residential building stock is estimated from survey data of per capita floor space.

Source: Lawrence Berkeley Laboratory, Report No. LBL-33867.

situation by the end of 1989. Buildings are also relatively new. Close to 80 percent of current building stock has less than 20 years of service.

8.7 A great part of China is under the impact of the east Asian monsoon. Each year from October to March, cold winter monsoons from Siberia and the Mongolian plateau sweep down southward. This climate condition makes a large portion of China very dry and cold in the winter. Extreme differences in winter temperatures can reach more than 40°C between the north and the south. Compared with other regions of the world at the same latitudes, China's winter temperatures are 5-20°C lower on the average from south to north. This climate condition determined that extensive winter space-heating is needed in about two thirds of China.

8.8 Summer is long and humid in areas to the south of Yangzi river. At present, most households and offices use electric fans to drive off summer heat. Potential for the use of air conditioners is great.

8.9 In 1986 the Ministry of Construction introduced the "Energy-Efficient Design Standards for Residential Buildings in Heating Zone" and began to experiment on demonstration projects. The standards set two goals for saving space-heating energy. The first goal was to reduce space-heating fuel intensity of new buildings to the level that would be 30 percent less than their 1981 value by 1990. The second goal was to further reduce space-heating energy intensity of new buildings to the level that would be 30 percent less than their 1990 value by 2000. Local governments in heating zone were required to formulate their own energy-efficient residential building standards according to the national code. But it was not until 1990 that a few cities, including Beijing and Xian, announced detailed local standards.

8.10 Progress in compliance with the building standards is not satisfactory because of the nonmandatory nature of the standards. Taking Beijing for example, from 1987 to 1990, the floor space of new residential buildings built up to par with the standards (most of it from demonstration projects) only accounted for about 10 percent of the total new residential floor space constructed in the same period. The situations in other northern cities are considered to be worse.

Energy Use

8.11 Residential energy use in China has two distinctive features: (a) massive use of low-grade energy sources such as coal and solid biomass, and (b) space heating and cooking dominate end uses. These features reflect China's special climate condition as well as relatively low standard of living.

8.12 The residential sector consumed about 430 MTCE energy in 1990, including 170 Mt coal, 240 Mt dry firewood, 280 Mt dry crop stalks, and 48 billion kWh electricity. Consumptions of gaseous fuel and cogenerated heat were small. More details are revealed in Table 8.3.

8.13 Cooking and space heating are responsible for an unusually high percentage share of fuel consumption, accounting for about 95 percent of total residential energy use in 1990. Electricity's share increased from less than 2 percent in 1980 to about 5 percent in 1990. In comparison, over 60 percent of the U.S. residential energy use is from electricity.

8.14 Large-scale biomass consumption is a striking feature of residential energy use in China. The growth rate of biomass consumption is gradually diminishing as end-use efficiency improves and coal becomes more accessible. Biomass still commanded about 65 percent of residential energy use in 1990, compared with its share of 70 percent in 1980. Current firewood consumption is estimated to exceed sustainable amount by 40 percent. About half of the available crop residues are also consumed for cooking and space-heating. This practice reduces the amount of organic materials that needs to be returned to the soil.

8.15 While anthracite resources in China are abundant and the quality is generally high, current anthracite supplies to the residential sector seem to be inadequate. The annual production of anthracite is about 200 Mt. Only 30 Mt is distributed to the residential sector while twice as much may be needed according to current cooking coal use. Similar situation exist in natural gas supply with more than 80 percent of it being used by industries.

8.16 **Characteristics of Urban Residential Energy Use.** Energy consumption of urban households is dominated by coal, which made up of about 75 percent of urban residential energy use in 1990 (Table 8.4). The growth rates of demand for electricity and gaseous fuel from 1985 to 1990 were about 17 and 18 percent per year, while that of coal use was negligible.

Table 8.3: RESIDENTIAL ENERGY USE BY ENERGY SOURCE, 1980, 1990
(MTCE)

	Biomass /a	Coal /b	Kerosene	Gaseous fuel /c	Heat /d	Electricity
1980	228.7	82.6	1.5	1.7	1.6	4.3
1981	233.7	86.3	1.7	1.8	1.6	4.8
1982	238.8	88.9	1.5	1.8	1.6	4.9
1983	244.0	93.3	1.8	2.0	1.7	5.5
1984	249.4	99.8	2.2	2.4	1.8	6.4
1985	254.8	111.6	1.8	2.9	1.9	9.0
1986	260.4	113.0	2.0	3.6	2.2	10.0
1987	266.1	117.7	1.9	4.0	2.7	11.6
1988	272.0	125.1	1.8	5.2	2.6	13.9
1989	277.4	121.7	1.9	6.2	2.8	16.0
1990	283.0	119.2	1.5	6.6	3.1	19.4

/a Figures are linearly extrapolated from 1979 and 1987 data. Biomass includes mostly firewood and crop stalks.
/b Includes raw coal and briquettes.
/c Includes LPG, natural gas, and gases derived from coal.
/d cogenerated heat for district heating.

Source: Lawrence Berkeley Laboratory, Report No. LBL-33867.

8.17 **Characteristics of Rural Residential Energy Use.** Rural households show quite different patterns of energy use from those of urban households. Although coal dominates modern energy use, it is overshadowed by the enormous amount of biomass consumption in the rural areas. In 1987, biomass commanded about 80 percent of rural household energy use while coal only contributed 18 percent. Kerosene is considered to be mostly used for lighting. About 40 million rural households still have no access to electricity. Table 8.5 reveals survey data on rural household energy use in 1979 and 1987.

8.18 If current biomass consumption is to be replaced by coal, about 160 MTCE, or 230 Mt raw coal—approximately one fifth of current total coal production—would be needed. By guiding the energy transition toward levels of modern and sustainable uses of biomass and other renewable energy sources, the government plays an essential role in minimizing the energy stresses of urbanization.

8.19 **Electricity Use.** Because of the rapid increase in appliance ownership, lighting has become a much less important component of residential electricity use today than in the early 1980s. For an above-average urban household that owns a refrigerator,

Table 8.4: URBAN RESIDENTIAL ENERGY MIX, 1980-90
(MTCE)

	Raw coal /a	Bri-quettes /a	Kero-sene	LPG	Town gas /b	Cogen. heat	Elec-tricity
1980	33.2	13.2	0.1	0.7	1.0	1.6	2.5
1981	34.3	14.3	0.1	0.8	1.0	1.6	2.8
1982	34.4	15.5	0.1	0.8	1.0	1.6	2.8
1983	35.7	16.8	0.1	1.0	1.0	1.7	3.2
1984	38.0	18.2	0.1	1.0	1.4	1.8	3.7
1985	42.7	19.7	0.1	1.6	1.3	1.9	5.0
1986	43.0	20.9	0.2	2.0	1.6	2.2	5.9
1987	42.6	22.2	0.1	2.1	1.9	2.7	6.6
1988	43.4	23.6	0.2	2.3	2.9	2.6	7.9
1989	39.1	25.1	0.1	2.6	3.6	2.8	9.1
1990	36.9	26.6	0.2	2.7	3.9	3.1	11.0

/a Figures are linear extrapolation of 1981, 1985, and 1988 data. Raw coal use is calculated by subtracting briquettes consumption from total coal use.
/b Town gas includes natural gas and gases derived from coal.

Source: *Statistical Yearbook of China, 1992.*

a color TV set, and a clothes washer, lighting may only account for 10-15 percent of its annual electricity use. On the other hand, for an average rural household, lighting still accounts for most of its annual electricity use. The greatly changed residential electricity consumption pattern is revealed in Table 8.6.

Energy Efficiency

8.20 Households in China not only consume great amounts of inferior energy sources such as coal and solid biomass, but also consume energy inefficiently, resulting in more pollution and fewer energy services per unit energy consumed. In rural areas, firewood is often burned in stoves that have roughly 10 percent heat efficiency. In many urban households, raw coal is burned for daily use. Coal-fired stoves are still popular for space heating. In addition, most buildings are simply constructed, with minimum insulation, which increases energy use and decreases comfort.

8.21 Efforts have been made to improve energy services in residential sector since the late 1970s. The massive efficient-stove program in rural areas and the promotion of gaseous fuel and honeycomb coal briquettes in urban areas are successful examples. Many

Table 8.5: RURAL RESIDENTIAL ENERGY MIX, 1979 AND 1987
(MTCE)

Materials	1979	%	1987	%
Crop stalks	113.7	43.6	130.3	39.2
Dung cake	6.3	2.4	3.2	1.0
Firewood	103.8	39.8	132.6	39.9
Coal	32.6	12.5	59.6	17.9
Kerosene	1.5	0.6	1.9	0.6
Electricity	3.1	1.2	5	1.5
Total	261.0	100.0	332.6	100.0

Source: Lawrence Berkeley Laboratory, Report No. LBL-33867.

Table 8.6: ESTIMATES OF RESIDENTIAL ELECTRICITY END USES, 1981 VERSUS 1989
(billion kWh)

	Lighting	Refrigerators	TVs	Fans	Clothes washers	Other
1981	10	0.1	0.5	0.6	0	0.6
1989	15	10	7	4	2	2

Source: Lawrence Berkeley Laboratory, Report No. LBL-33867.

other conservation efforts such as developing district heating and adopting energy-efficient building standards, however, are still preliminary and experimental.

8.22 **Cooking and Domestic Water Heating.** Cooking is the number one energy use in China's residential sector, due, in part to the inefficient use of solid fuels. Most rural households use firewood stoves and most urban households, coal fired stoves. Only about 10 percent of current urban population use gaseous fuel for cooking. The usage of hot water is limited. Households boil water for tea and cooking and other necessary daily uses. Most households do not have hot-water shower devices which, however, are gaining popularity with increasing accessibility of gaseous fuel.

8.23 The promotion of honeycomb briquettes has been a major residential coal-saving activity. Firing honeycomb briquettes in efficient stoves could achieve heat efficiency as high as 40 percent, about three times that of stoves burning raw coal. In daily practice, heat efficiency may be significantly lower, usually about 20 percent. In comparison, heat efficiency of gas-fired stoves usually reaches 50 percent.

8.24 While cooking fuel is basically guaranteed for urban households, many rural families still suffer from shortages. Because ordinary firewood stoves have only about 10 percent heat efficiency, the demand for firewood and crop residues in rural areas is often excessive. Seeing the danger of chronic rural fuel shortages and unsustainable firewood consumption, the government launched efficient-stove and tree-planting programs in the early 1980s. By 1987, about 45 percent of rural households had been equipped with energy-efficient stoves with rated heat efficiency of 25-30 percent. This program was estimated to have been able to save 20 MTCE of firewood per year as of 1987.

8.25 One other energy-efficient and much cleaner option for rural cooking is the utilization of biogass, a viable fuel source in areas to the south of Yangzi river. Programs of constructing biogas digesters for rural households has been undertaking for about two decades. The results are mixed, depending on regional conditions and the commitment of both the households involved and local management.

8.26 **Space Heating.** There are three modes of space heating in urban areas: coal-fired stoves, central heating provided by small boilers, and district heating provided by large boilers or cogeneration plants. Rural households use either firewood or coal-fired stoves for space heating. About two thirds of the urban households in heating zone are heated by coal-fired stoves and the rest is heated mostly by small-boiler central heating systems. The share of district heating systems is small, probably about 5 percent.

8.27 Stove heating is unhealthy and low in comfort levels. Households using heating stoves often have lower indoor temperatures and shorter heating time. Usually only one room is heated and the stove may be moved outside of the apartment in the night to avoid CO poisoning. For these reasons, households that use stoves for space heating have much lower seasonal heating fuel intensities than those using central heating facilities--18 versus 30 kgce per square meter floor space.

8.28 Centrally heated buildings are mostly serviced by small boilers with typical capacities of 1-4 ton steam per hour (ts/h). One ts/h boiler capacity typically heats a floor area of about 4,000 m^2, approximately 100 households. Small-boiler central heating systems have two major energy-efficiency problems: low capacity factor (average heating load/rated boiler heating capacity in terms of heated floor space) and poor boiler heat efficiency. While the former is usually related to the design and operation of the heating systems, the latter is basically due to outdated boiler manufacturing technology. With the combined problems of the distribution network and the boiler itself, small-boiler central heating systems usually have 50 percent or lower overall efficiency.

8.29 District heating systems usually utilize medium to large industrial boilers (10, 20 and 40 ts/h). The 10 ts/h boilers are most popular, with a usual 70-80 percent rated heat efficiency. Problems, such as partial loads, operation by unskilled personnel, and the use of low-quality coal, that exist in small boiler systems also impair the energy efficiency of large-boiler heating systems. Conservation measures may yield significant economic benefits in the case of large boilers because of the high replacement costs. The residential sector does not benefit much from existing cogeneration capacity which primarily serves industrial users. With serious shortages in electricity supply at present, heat supply may be sacrificed for power generation.

8.30 Technically speaking, large district heating systems are efficient heating modes in northern China, giving the climate condition and the dwelling pattern. In practice, difficulties are often encountered when these systems try to meet expectations. Reports indicate that some of the newly built district-heating systems actually run less efficiently than many of the well-operated small-boiler systems because of insufficient hook-ups or the slowness in making new hook-ups.

8.31 The efficiency of China's central heating systems is significantly impaired by the poor quality of heat distribution networks, which are often not well-insulated and are operated with malfunctioning equipment. The average heat loss of the distribution networks is about 15 percent, while 10 percent is considered to be appropriate. The unbalanced hydraulic working state and the lack of flow control valves create problems such as overheating for households near the mains and underheating for those end-of-the-pipe households. The common practice of resolving the problem is to increase pumping capacity which reduces boiler operation efficiency because of reduced outgoing and returning water temperature difference.

8.32 Promoting central heating systems may not help save heating coal use if we compare their fuel intensity to that of stoves. But using central heating facilities represents a major improvement of the standard of living for urban households in northern China with respect to both thermal comfort and indoor air quality. By applying district heating, the government would also have much easier control over the emissions of air pollutants.

8.33 Poor thermal integrity of residential buildings in China reduces thermal comfort and increases space conditioning energy use. Solid bricks are the predominant wall material in China. Heat loss is substantial through exterior walls and roofs that have only minimum insulation. Table 8.7 compares some heat performance features of typical apartment buildings in northern China with those of Canada residential buildings in areas of similar heating degree-days. The difference are striking. Since Canadian residential buildings are mostly wooden structures, a low heat transfer coefficient is achieved more easily. Using hollowed bricks and double-glazed windows can reduce heat losses in buildings significantly.

8.34 **Lighting.** Although fluorescent lamps are commonly used in urban households, incandescent light bulbs are still the popular choice for lighting. This can be partly informed from the annual production of light bulbs which registered 2 billion for incandescent bulbs and 200 million for fluorescent lamps in 1990. Lighting lumen levels are usually low in Chinese households and people usually do their best to save electricity.

Table 8.7: HEAT-TRANSFER COEFFICIENTS OF TYPICAL MULTI-STORY CHINESE APARTMENT BUILDINGS VERSUS THOSE OF NORTH AMERICAN HOUSES

	Exterior wall (W/m^2-°C)	Window (W/m^2-°C)	Roof (W/m^2-°C)
Beijing			
Present status	1.57	6.40	1.26
New standards	1.28	6.40	0.91
Harbin			
Present status	1.28	3.26	0.77
New standards	0.73	3.26	0.64
Canada			
Comparable to Beijing	0.36	2.86	0.23-0.40
Comparable to Harbin	0.27	2.22	0.17-0.31

Source: Lawrence Berkeley Laboratory, Report No. LBL-33867.

Installations of compact fluorescent lamps are rare because their high purchasing costs and consumer's disbelieve in their reliability.

8.35 Appliances. Major electricity-consuming appliances include refrigerators, TV sets, clothes washers, and electric fans. Air conditioners are still rare in households. Popular domestic-made refrigerators (two-door 170 liter) consume about 400 kWh electricity per years which is significantly higher than similar contemporary models made in Japan or Korea. For example, the average electricity consumption of 200 liter two-door Korean models already reached 240 kWh/year in 1986.

Potential for Improvement

8.36 A household would be able to save about 20 percent of its cooking coal by switching from raw coal to honeycomb briquettes, other conditions being equal. Switching from coal to gaseous fuel represents the largest efficiency gain and help to reduce indoor as well as ambient air pollution. Limited natural gas resources and financial and technological difficulties in large-scale coal gasification may hinder this process.

8.37 Many least-cost measures, such as better quality coal for boilers and better training for boiler operators, can save coal use in central heating. Resolving problems in the distribution networks and optimizing boiler operation will significantly improve the energy efficiency of existing central heating systems. In a demonstration project, a team of engineers is able to raise the seasonal operation energy efficiency of a central heating system (with a 10 ts/h boiler) from 55 percent to 64 percent by installing new flow-control valves and a computer system for boiler operation. The cost of the measure is only Y 50 per annual TCE which is substantially lower than the cost of bring 1 TCE coal to the market.

8.38 Improving building thermal integrity is a major step in saving space conditioning energy use and is the primary goal of energy efficient building standards. The long-term effect of high thermal-integrity buildings cannot be underestimated. Unfortunately building construction in the past have failed to adopt this important energy-saving measure and is continuing to perform poorly in this respect due to inadequate regulatory enforcement, insufficient technical support, temporary financial constraint, and the pressure of soaring housing demand.

8.39 Improving lighting efficiency mainly lies in the hands of the lamp manufacturers because current household lighting practice is already very frugal. The cost-effectiveness of introducing compact fluorescent lamps depends on what wattage of incandescent bulbs that are replaced, the time of use, and electricity prices.

8.40 Great improvement can be achieved in reducing refrigerator electricity consumption. For example, a modified two-door 177 liter model produced by a Shanghai plant consumes 292 kWh/year, representing a 27 percent reduction in electricity use compared with popular comparable models. The Korean refrigerator industry, with the assistance from the government, was able to reduce the average unit electricity use of 200 liter refrigerators from 672 kWh/year in 1980 to 240 kWh/year in 1986. The Korean experience is a good example of the potential and swiftness of possible energy efficiency improvement for refrigerators.

Energy Use and Efficiency Trends

8.41 The demand for electricity and gaseous fuels will continue to increase strongly and the dominance of coal will gradually decline. But a large decrease in coal use is unlikely in the near future because of the nature of domestic energy resources and the large space-heating demand.

8.42 From the experiences in the 1980s, construction of district-heating facilities (especially cogeneration facilities) is quite expensive. From the aspect of providing equal services with minimum pollution and high energy efficiency, district heating systems do have advantages over small coal-fired central heating systems and stoves in heating-zone areas. But future technological development may also make small coal-fired central heating systems attractive and the increasing availability of gaseous fuels is also likely to make gas-fired heating a possible alternative.

8.43 The continuing efficient stove program aims at equipping all rural households with energy-efficient stoves by the year 2000. If the goal materializes, potential firewood and crop stalk savings are considerable. Although end-use efficiency is of great importance to China's rural energy development, it is unlikely that conservation alone can solve rural fuel supply problems. History has shown that while people have been using more efficient equipment, they are also using more energy as the standard of living rises and their lifestyle changes. Thus, it is essential to develop other alternative fuel supplies. The Chinese government has shown strong interest in planning a sustainable energy future for rural areas and has made great efforts to address this important issue.

8.44 Rising household incomes are expected to foster two developments in residential energy use. Domestic water heating (for showing) has become an increasingly popular activity as gaseous fuels become more accessible. Market research shows that the demand for air conditioners has grown significantly since 1990. Such trends will lead to greater demand for gaseous fuels and electricity in the future.

8.45 Compared with appliances used in American households, those used in China are small and low-power machines, especially in the categories of refrigerators and clothes washers. The Chinese households are also much more conscious about electricity used by appliances. Continuing increase in personal income has made possible for households to purchase larger refrigerators and TV sets and clothes washers with spinning cylinders instead of single washing cylinder washers. This trend is sure to offset some gains in energy efficiency.

B. Commercial Buildings

Sector Profile

8.46 All nonindustrial and nonresidential civilian buildings are considered as commercial buildings. According to the latest survey, commercial building stock stood at 1,019 million m^2 in 1989. About 52 percent of the total stock was classified as commerce buildings, i.e., those that house shops, restaurants, and other for-profit businesses. Office buildings accounted for 30 percent of the total stock and the share for educational and academic buildings was 3 percent. The unclassified commercial building stock was significant with a 15 percent share of the total stock.

8.47 Commercial buildings in China basically share similar physical characteristics with residential buildings. Most of them are not insulated and about half of them need extensive winter space heating. Low-rise buildings contribute to much of the total floor space.

8.48 Construction of new commercial buildings has been intensive since the late 1970s. The large increase of fully conditioned commercial buildings (with complete cooling and heating systems) is a major development with great long-term impact on commercial building energy use.

Energy Use

8.49 Commercial buildings, presumably all in urban areas, consumed about 40 MTCE energy in 1990 in which coal contributed 55 percent and electricity shared 28 percent. Table 8.8 depicts the mix of energy demand from commercial buildings.

Table 8.8: ENERGY USE BY ENERGY SOURCE IN THE COMMERCIAL SECTOR, 1980-90 (MTCE)

	Coal	Oil	Gas	Cogen. heat	Electricity
1980	11.1	4.1	0.3	0.7	3.5
1981	11.7	3.6	0.3	0.7	3.8
1982	12.6	3.5	0.2	0.7	4.1
1983	13.8	3.7	0.2	0.7	4.6
1984	15.7	3.3	0.2	0.8	5.2
1985	16.6	3.9	0.3	0.3	6.5
1986	17.6	3.7	0.4	0.3	6.8
1987	18.4	3.8	0.5	0.4	8.0
1988	20.4	5.2	0.5	0.5	9.2
1989	20.8	6.0	0.5	0.4	10.1
1990	21.8	5.6	0.5	0.5	11.3

Source: *China Energy Statistical Yearbook, 1991.*

8.50 Energy is mainly used for space heating and lighting in commercial buildings. Cooking fuel is also significant because of the popularity of restaurants and work-unit cafeterias in China. Other uses include public bathhouses and teahouse boilers.

8.51 Lighting is still the largest electricity user in commercial buildings. Buildings with heating, ventilation and air conditioning (HVAC) systems are becoming important energy users in large cities and coastal urban areas.

Energy Efficiency

8.52 Most restaurants and cafeterias use raw coal as cooking fuel, resulting in low energy efficiency and high air pollution.

8.53 Coal or charcoal-fired stoves provide space heating for about 75 percent of the floor space in heated commercial, indicating the low quality of energy service in commercial buildings. Seasonal fuel intensity of space heating is lower in commercial buildings than in residential buildings, registering 15 kgce/m^2 for stove-heated space and 20 kgce/m^2 for centrally heated space.

8.54 Lighting efficiency is considered low because most fluorescent fixtures in commercial buildings are equipped with electromagnetic ballasts and large wattage incandescent lamps are also widely used.

8.55 Most HVAC systems installed in space-conditioned commercial buildings are inefficiently operated because of poor building design, lack of maintenance and mismanagement.

Potential for Improvement

8.56 There have been attempts to use large honeycomb briquettes for commercial cooking and teahouse boilers. Many commercial users such as restaurants prefer raw coal because they usually need fast combustion and high flames. For these users, gaseous fuel may be the only favorable substitution. Using briquettes in small boilers, however, could be an effective measure of saving coal and reducing air pollution.

8.57 Lighting efficiency improvement is considered great in commercial buildings because of large wattage lamps are used and the operating time is usually long. High-efficiency fluorescent tubes and electronic ballasts are considered very cost-effective measures. Estimate rate the electronic ballast/fluorescent lamp system 25 percent more efficient than the electromagnetic ballast/fluorescent lamp systems. A 36W high-efficient TLD fluorescent tube is able to put out the same amount of lumens as a 40W conventional TL tube.

8.58 Many tourist hotels with HVAC systems do not have any better insulation than ordinary hotels. Electricity can be saved by improving the thermal integrity of the building envelope, which includes window improvement, wall and roof insulation, and better building design.

Energy Use and Efficiency Trends

8.59 Until recently there have been limited energy-conservation efforts in commercial buildings and there is no specific conservation policy aimed at commercial buildings. Since the stock of modern hotels and office buildings is increasing at rapid rate in major cities and coastal areas, HVAC systems is likely to emerge as a major energy use in commercial buildings in the next 10 years. There has also been a fast increase in the use of room air conditioners in offices in recent years, so electricity use for air conditioning will increase dramatically.

8.60 In order to save coal and electricity, there is an urgent need to improve the thermal integrity of commercial buildings. This calls for the establishment and enforcement of energy-efficient commercial building standards. If current practice continues, the high-volume construction in the next 10 years will have a significant impact on energy demand of commercial buildings in the decades to come. Retrofitting old buildings is often costly.

APPENDIX A

Case Study Analyses: Forecasted Applications and Impacts on Energy Use and Emissions

This section presents the results of forecasts of the "business as usual" (BAU) and "accelerated" (ACCEL) scenarios for adoption of each of the technologies or modifications evaluated as case studies. Both BAU and ACCEL scenarios were developed from information supplied in the Background Reports and by studying trends in the respective industries in other countries. Technical judgement was used to develop the respective scenarios, which were then used to calculate the forecasts of changes in energy consumption and emissions for 2000 and 2010.

Various ratios were also calculated, including the required investment cost (per unit of processing capacity) necessary to adopt the various technologies, and the investment per annual tonne of CO_2 emission reduction and per annual TCE saved. These ratios are reported in the full outputs of each case study evaluation and in the summary table included in this Appendix. However, the numbers are a only a rough guide to the attractiveness of each measure and are therefore not highlighted.

A better guide to relative economic attractiveness is the net annualised benefit (or cost) per tonne CO2 reduction or per TCE saved. These figures take into account the fact that many measures are indeed positively beneficial to the industry or plant concerned: these data are developed in a separate report. Put simply, energy efficiency is usually very good business, and the reduced emissions of global warming gases that are achieved at the same time are an extra bonus.

Calculation data are reported for the following case studies:

Iron and Steel Industry

M1 Open hearth converters replaced by BOF systems
M2 Continuous casting
M3 Reheat furnace renovation
M4 BF gas recovery for steam/electricity generation

Non Ferrous Metals

M5 Aluminium plant renovation

Building Materials

B1 Replace old dry kilns by preheater/precalciner systems
B2 Wet to dry conversion
B3 Vertical shaft kiln renovation

Paper

L1 Black liquor recovery
L2 Cogeneration in a paper mill

Textiles

T1 Cogeneration in a textile mill
T2 NaOH recovery
T3 Energy management

Chemicals

CH1 Medium size ammonia plant renovation
CH2 Small ammonia plant renovation and waste heat recovery
CH3 New membrane process at NaOH plant

Equipment

E1 High efficiency motors
E2 Variable speed motors
E3 Electric motor repair centres
E4 Steam traps

CASE STUDY ANALYSIS NUMBER M1 Open Hearth Converters Replaced by BOF

		Without project Open Hearth	With project BOF	
Net energy use	kgCE/t	75.11	26.60	
CO2 emission	kg/t	92.02	40.58	
SO2 emission	kg/t	14.23	0.60	
TSP emission	kg/t	222.05	45.20	
Investment for CS	million RMB	0	1050	
Capacity for CS	million TPY	2.60	3.00	
Investment per TPY	RMB/tpy BOF		350	
Present cap. OH	million TPY	11.7		
Calculated -- financial -- IRR			16.1	percent
Calculated payback inc construction time			13	years

		1990	2000	2010	
BAU FORECAST					
Capacity OH	10^6 tpy	11.7	8.7	8.7	
Capacity BOF	10^6 tpy	0.0	3.0	3.0	
Energy OH	10^3 tce/yr	878.8	653.5	653.5	
Energy BOF	10^3 tce/yr	0	79.8	79.8	
Total energy	10^3 tce/yr	878.8	733.3	733.3	
Energy saved	10^3 tce/yr	0	145.5	145.5	**
CO2	10^3 t/y	1076.6	922.3	922.3	
SO2	10^3 t/y	166.5	125.6	125.6	
TSP	10^3 t/y	2598.0	2067.4	2067.4	
CO2 removal	10^3 t/y	0	154.3	154.3	**
Investment	million RMB		1050.0	1050.0	
Invest CO2 removal	RMB per t/y		6804	6804	**
Invest TCE saved	RMB per TCE/y		7215	7215	**
ACCELERATED FORECAST					
Capacity OH	10^6 tpy	11.7	8.7	0.0	
Capacity BOF	10^6 tpy	0.0	3.0	11.7	
Energy OH	10^3 tce/yr	878.8	653.5	0.0	
Energy BOF	10^3 tce/yr	0.0	79.8	311.2	
Total energy	10^3 tce/yr	878.8	733.3	311.2	
Energy saved	10^3 tce/yr	0.0	145.5	567.6	**
CO2	10^3 t/y	1076.6	922.3	474.8	
SO2	10^3 t/y	166.5	125.6	7.0	
TSP	10^3 t/y	2598.0	2067.4	528.8	
CO2 removal	10^3 t/y	0.0	154.3	601.8	**
Investment	million RMB		1050.0	4095.0	
Invest CO2 removal	RMB per t/y		6804	6804	**
Invest TCE saved	RMB per TCE/y		7215	7215	**

NOTES

1 Current OH capacity about 13 MMtpy steel of which about 10 percent will convert to electric steel making.

2 This leaves 11.7 MMtpy OH capacity to be converted to BOF.

3 It is assumed that only one large plant (capacity 3 MMtpy after conversion, like Anshan) will convert to BOF by 2000.

4 For the BAU case, it is assumed no other conversion occurs before 2010, the cost being high. IRR and payback not particularly attractive.

5 For the ACCEL case, it is assumed that funding is made available to all existing OH operators and conversion is completed by 2010.

6 Note that original capacity of 0 for BOF does not imply this technology does not exist in China; for this exercise, only the conversion of 11.7 OH capacity is considered.

CASE STUDY ANALYSIS NUMBER M2 Continuous Casting Replacing Ingot Route

		Without project ingot castg	With project con casting
Net energy use	kgCE/t	64.79	24.19
CO2 emission	kg/t	42.18	15.75
SO2 emission	kg/t	1.77	0.66
TSP emission	kg/t	0.71	0.27
Investment for CS	10^6 RMB	0	1580
Capacity for CS	10^6 tpy	1.60	3.50
Investment per TPY	RMB/tpy concast		451
1990 pig iron cap	10^6 tpy	62.4	
2010 pig iron cap	10^6 tpy	62.4	

Calculated -- financial -- IRR	18.6	percent
Calculated payback inc construction time	9	years

BAU FORECAST		1990	2000	2010	
Cap ingot casting	MM tpy	47.6	45.8	31.4	
Cap con casting	MM tpy	14.8	16.6	31.0	0.237
Cap total	MM tpy	62.4	62.4	62.4	
Energy ingot cast.	10^3 tce/y	3084.0	2967.4	2034.4	
Energy concastg	10^3 tce/y	358.0	401.6	749.9	
Total energy	10^3 tce/y	3442.0	3368.9	2784.3	
Energy saved	10^3 tce/y	0.0	73.1	657.7	**
CO2	10^3 t/y	2240.9	2193.3	1812.7	
SO2	10^3 t/y	94.0	92.0	76.0	
TSP	10^3 t/y	37.8	37.0	30.7	
IF SAME PERCENT CONCASTING					
Cap ingot casting	MM tpy	47.6	47.6	47.6	
Cap con casting	MM tpy	14.8	14.8	14.8	
Cap total	MM tpy	62.4	62.4	62.4	
Energy ingot cast	10^3 tce/y	3084.0	3084.0	3084.0	
Energy concastg	10^3 tce/y	358.0	358.0	358.0	
Total energy	10^3 tce/y	3442.0	3442.0	3442.0	
ENERGY SAVED WITH CONCAST		0.0	73.1	657.7	**
IF SAME PERCENT CONCASTING					
CO2	10^3 t/y	2240.9	2240.9	2240.9	
Reduction in CO2	10^3 t/y	0.0	47.6	428.2	**
Investment	10^6 RMB		812.6	7313.1	total to 2000
Invest CO2 removal	RMB per tpy		17080	17080	**
Invest TCE saved	RMB per TCE/y		11119	11119	**

ACCELERATED FORECAST				
Cap ingot casting	MM tpy	47.6	45.8	12.5
Cap con casting	MM tpy	14.8	16.6	49.9
Total capacity	MM tpy	62.4	62.4	62.4
Energy ingot cast	10^3 tce/y	3084.0	2967.4	809.9
Energy con cast	10^3 tce/y	358.0	401.6	1207.1

NOTES

1 Estimate of current continuous casting capacity based on 23.7% of pig iron production.

2 Assume 90% of future steel make will be processed by ingot or concast routes.

3 For new capacity, 90% will be concast anyway. By 2000, 50% of pig iron will be concast, 70% by 2010 for BAU and 90% for ACCEL case (as stated by the Ministry).

4 By material balances, amounts of existing ingot casting capacity to convert to concast to reach these objectives may be estimated -- see summary below.

Calculation summary

	1990		BOTH CASES		2000		
	MM tpy	percent	New	New pct	Old	Total	Total pct
Ingot	47.6	76.3	3.7	10	45.8	49.5	50
Concast	14.8	23.7	32.9	90	16.6	49.5	50
Total	62.4	100.0	36.6		62.4	99	
	(pig iron)			(pig iron	90.0	pct of steel)	
					steel	110	

BAU CASE		2010		
New	New pct	Old	Total	Total pct
6.4	10	31.4	37.8	30
57.2	90	31.0	88.2	70
63.6		62.4	126.0	
	(pig iron	90.0	pct of steel)	
		steel	140.0	

ACCEL CASE		2010		
New	New pct	Old	Total	Total pct
6.4	10	12.5	18.9	15
57.2	90	49.9	107.1	85
63.6		62.4	126.0	
	(pig iron	90.0	pct of steel)	
		steel	140.0	

Energy con cast	10^3 tce/y	358.0	401.6	1207.1	
Total energy	10^3 tce/y	3442.0	3368.9	2017.0	
Energy saved	10^3 tce/y	--	73.1	1425.1	**
CO2	10^3 t/y	2240.9	2193.3	1313.2	
SO2	10^3 t/y	94.0	92.0	55.1	
TSP	10^3 t/y	37.8	37.0	22.3	
IF SAME PERCENT CONCASTING					
Cap ingot casting	MM tpy	47.6	47.6	47.6	
Cap con casting	MM tpy	14.8	14.8	14.8	
Cap total	MM tpy	62.4	62.4	62.4	
Energy ingot cast	10^3 tce/y	3084.0	3084.0	3084.0	
Energy concastg	10^3 tce/y	358.0	358.0	358.0	
Total energy	10^3 tce/y	3442.0	3442.0	3442.0	
ENERGY SAVED WITH CONCAST		0.0	73.1	1425.1	**
IF SAME PERCENT CONCASTING					
CO2	10^3 t/y	2240.9	2240.9	2240.9	
Reduction in CO2	10^3 t/y	0.0	47.6	927.7	**
Investment	10^6 RMB		812.6	15845.1	total to 2000
Invest CO2 removal	RMB per tpy		17080	17080	**
Invest TCE saved	RMB per TCE/y		11119	11119	**

CASE STUDY ANALYSIS NUMBER M3 Reheat Furnace Renovation

		Without project old furnace	With project (renovated)
Net energy use	kgCE/t	101	90
CO2 emission	kg/t	65.30	58.20
SO2 emission	kg/t	2.74	2.44
TSP emission	kg/t	1.02	0.91
Investment for CS	10^6 RMB	0.000	0.282
Capacity for CS	million TPY	0.120	0.132
Investment per TPY	RMB/tpy renov.furnaces		2
Present capacity	10^6 TPY	50	old rolling mills

Calculated -- financial -- IRR 36.7 percent
Calculated payback inc construction time 1 year

		1990	2000	2010	
BAU FORECAST					
Capacity old fur	10^6 tpy	50.0	8.3	0.0	
Capacity renov.	10^6 tpy	0.0	41.7	50.0	
Energy old fur	10^3 tce/yr	5045.0	837.5	0.0	
Energy renov.	10^3 tce/yr	0.0	3748.8	4495.0	
Total energy	10^3 tce/yr	5045.0	4586.3	4495.0	
Energy saved	10^3 tce/yr	0.0	458.7	550.0	**
CO2	10^3 t/y	3265.0	2968.9	2910.0	
SO2	10^3 t/y	137.0	124.5	122.0	
TSP	10^3 t/y	51.0	46.4	45.5	
CO2 removal	10^3 t/y		296.1	355.0	**
Investment	10^6 RMB		89.1	106.8	
Invest CO2 removal	RMB per tpy		301	301	**
Invest TCE saved	RMB per TCE/y		194	194	**
ACCELERATED FORECAST					
Capacity old fur	10^6 tpy	50.0	0.0	0.0	
Capacity renov.	10^6 tpy	0.0	50.0	50.0	
Energy old fur	10^3 tce/yr	5045.0	0.0	0.0	
Energy renov.	10^3 tce/yr	0.0	4495.0	4495.0	
Total energy	10^3 tce/yr	5045.0	4495.0	4495.0	
Energy saved	10^3 tce/yr	0.0	550.0	550.0	**
CO2	10^3 t/y	3265.0	2910.0	2910.0	
SO2	10^3 t/y	137.0	122.0	122.0	
TSP	10^3 t/y	51.0	45.5	45.5	
CO2 removal	10^3 t/y		355.0	355.0	**
Investment	10^6 RMB		106.8	106.8	
Invest CO2 removal	RMB per tpy		301	301	**
Invest TCE saved	RMB per TCE/y		194	194	**

NOTES

1 Capacity for rolling is in excess of 50 mm tpy and there are about 480 furnaces of all types installed, say 370 need attention.

2 It is assumed all these will be renovated and upgraded by 2010.

3 For BAU, it is assumed that renovation will take about 12 years from 1990 at a rate of about 30-40 furnaces per year.

4 For ACCEL case, it is assumed all renovation completed by 2000.

CASE STUDY ANALYSIS NUMBER M4 BF gas recovery for steam/elec. generation

		Without project no recovery	With project BF gas recovered
Net energy use	kgCE/t	108.6	59.3
CO2 emission	kg/t	70.7	31.2
SO2 emission	kg/t	3.0	0.2
TSP emission	kg/t	1.2	0.4
Investment for CS	10^6 RMB	0	17.45
Capacity for CS	10^6 TPY	0	0.505 pig iron output
Investment per TPY	RMB/tpy BF		34.55
Present capacity	10^6 TPY	10 mm tpy pig iron, no recovery	

NOTES

1 Example plant (Xingtai) produces about 500,000 tpy pig iron. It is assumed there are about 25 such plants, total capacity say 10 MM tpy, suitable for gas recovery system.

2 For BAU, assume 60% installed by 2000. For ACCEL case, 80%: all completed by 2010.

Calculated -- financial -- IRR 28.2 percent
Calculated payback inc construction time 7 years

		1990	2000	2010	
BAU FORECAST					
Capacity no rec	10^6 TPY	10.0	4.0	0.0	
Capacity with rec	10^6 TPY	0.0	6.0	10.0	
Energy no rec	10^3 tce/yr	1086.0	434.4	0.0	
Energy with rec	10^3 tce/yr	0.0	355.8	593.0	
Total energy	10^3 tce/yr	1086.0	790.2	593.0	
Energy saved	10^3 tce/yr	0.0	295.8	493.0	**
CO2	10^3 t/y	707.0	470.0	312.0	
SO2	10^3 t/y	29.7	13.2	2.2	
TSP	10^3 t/y	12.0	7.3	4.2	
CO2 removal	10^3 t/y		237.0	395.0	**
Investment	10^6 RMB		207.3	345.5	
Invest CO2 removal	RMB per t/y		875	875	**
Invest TCE saved	RMB per TCE/y		701	701	**
ACCELERATED FORECAST					
Capacity no rec	10^6 TPY	10.0	2.0	0.0	
Capacity with rec	10^6 TPY	0.0	8.0	10.0	
Energy no rec	10^3 tce/yr	1086.0	217.2	0.0	
Energy with rec	10^3 tce/yr	0.0	474.4	593.0	
Total energy	10^3 tce/yr	1086.0	691.6	593.0	
Energy saved	10^3 tce/yr	0.0	394.4	493.0	**
CO2	10^3 t/y	707.0	391.0	312.0	
SO2	10^3 t/y	29.7	7.7	2.2	
TSP	10^3 t/y	12.0	5.8	4.2	
CO2 removal	10^3 t/y		316.0	395.0	**
Investment	10^6 RMB		276.4	345.5	
Invest CO2 removal	RMB per t/y		875	875	**
Invest TCE saved	RMB per TCE/y		701	701	**

CASE STUDY ANALYSIS NUMBER MS Aluminium plant renovation

		Without project old equipmt	With project new equipmt
Net energy use	kgCE/t	2023.78	1858.97
CO2 emission	kg/t	1121.6	1038.2
SO2 emission	kg/t	45.8	42.7
TSP emission	kg/t	20.4	19.0
Investment	10^6 RMB	0	80.74
Capacity	10^6 TPY	0.470	0.500
Investment per TPY	RMB/tpy new equipment		161.480
Present capacity	10^6 TPY	6	
Final capacity	10^6 TPY	0	

Calculated -- financial -- IRR 84.3 percent
Calculated payback inc construction time 3 years

BAU FORECAST		1990	2000	2010	
Capacity old	10^6 TPY	6.0	4.0	0.0	
Capacity new	10^6 TPY	0.0	2.0	6.0	
Energy OH	10^3 tce/yr	12142.7	8095.1	0.0	
Energy BOF	10^3 tce/yr	0.0	3717.9	11153.8	
Total energy	10^3 tce/yr	12142.7	11813.1	11153.8	
Energy saved	10^3 tce/yr	0.0	329.6	988.9	**
CO2	10^3 t/y	6729.5	6562.8	6229.4	
SO2	10^3 t/y	275.0	268.8	256.3	
TSP	10^3 t/y	122.1	119.5	114.2	
CO2 removal	10^3 t/y		166.7	500.1	**
Investment	10^6 RMB		323.0	968.9	
Invest CO2 removal	RMB per t/y		1937	1937	**
Invest TCE saved	RMB per TCE/y		980	980	**

ACCELERATED FORECAST					
Capacity OH	10^6 TPY	6.0	3.0	0.0	
Capacity BOF	10^6 TPY	0.0	3.0	6.0	
Energy OH	10^3 tce/yr	12142.7	6071.3	0.0	
Energy BOF	10^3 tce/yr	0.0	5576.9	11153.8	
Total energy	10^3 tce/yr	12142.7	11648.3	11153.8	
Energy saved	10^3 tce/yr	0.0	494.4	988.9	**
CO2	10^3 t/y	6729.5	6479.4	6229.4	
SO2	10^3 t/y	275.0	265.7	256.3	
TSP	10^3 t/y	122.1	118.1	114.2	
CO2 removal	10^3 t/y		250.0	500.1	**
Investment	10^6 RMB		484.4	968.9	
Invest CO2 removal	RMB per t/y		1937	1937	**
Invest TCE saved	RMB per TCE/y		980	980	**

NOTES

1 There are 16 other similar plants to the Shandong works used for the case study, total alumina capacity about 6 mm tpy.

2 For BAU, assume one third -- about 5-6 plants -- renovated by 2000, for ACCEL case assume at least half, say 8 plants.

3 By 2010, assume all conversions are complete.

CASE STUDY ANALYSIS NUMBER B1 Replace old dry kilns by preheater/precalciner systems

		Without project old plant	With project new plant	
Net energy use	kgCE/t	286	161	
CO2 emission	kg/t	189.32	107.75	
SO2 emission	kg/t	2.32	1.68	
TSP emission	kg/t	21.43	2.82	
Investment for CS	10^6 RMB	0	457.99	
Capacity for CS	10^6 tpy	0.408	0.746	cement
Investment per TPY	RMB/tpy		614	
Present capacity	10^6 tpy	5		

Calculated -- financial -- IRR	16.9	percent
Calculated payback inc construction time	11	years

BAU FORECAST		1990	2000	2010	
Capacity old	10^6 tpy	6.0	3.0	0.0	
Capacity new	10^6 tpy	0.0	3.0	6.0	
Energy old	10^3 tce/yr	1716.3	858.2	0.0	
Energy new	10^3 tce/yr	0.0	482.2	964.4	
Total energy	10^3 tce/yr	1716.3	1340.4	964.4	
Energy saved	10^3 tce/yr	0.0	375.9	751.9	**
CO2	10^3 t/y	1135.9	891.2	646.5	
SO2	10^3 t/y	13.9	12.0	10.1	
TSP	10^3 t/y	128.6	72.8	16.9	
CO2 removal	10^3 tpy		244.7	489.4	**
Investment	10^6 RMB		1841.8	3683.6	
Invest CO2 removal	RMB per t/y		7526	7526	**
Invest TCE saved	RMB per TCE/y		4899	4899	**

ACCELERATED FORECAST		1990	2000	2010	
Capacity old	10^6 tpy	6.0	0.0	0.0	
Capacity new	10^6 tpy	0.0	6.0	6.0	
Energy old	10^3 tce/yr	1716.3	0.0	0.0	
Energy new	10^3 tce/yr	0.0	964.4	964.4	
Total energy	10^3 tce/yr	1716.3	964.4	964.4	
Energy saved	10^3 tce/yr	0.0	751.9	751.9	**
CO2	10^3 t/y	1135.9	646.5	646.5	
SO2	10^3 t/y	13.9	10.1	10.1	
TSP	10^3 t/y	128.6	16.9	16.9	
CO2 removal	10^3 tpy		489.4	489.4	**
Investment	10^6 RMB		3683.6	3683.6	
Invest CO2 removal	RMB per t/y		7526	7526	**
Invest TCE saved	RMB per TCE/y		4899	4899	**

NOTES

1 Original capacity of long dry kilns with waste heat boilers is assumed to be 3% of say 200 million tpy cement capacity, about 6 mm tpy.

2 For BAU case, assume half the kilns are renovated by 2000 -- this represents about 5 or 6 plants. Balance completed by 2010.

3 For ACCEL case, it is assumed all kilns converted by 2000 (say 10-12 production lines).

CASE STUDY ANALYSIS NUMBER 82 Wet to dry conversion

		Scenario 1 Without project wet process	with wet grinding, dry kiln With project dry process	
Net energy use	kgCE/t	248	170	
CO2 emission	kg/t	164.29	113.39	
SO2 emission	kg/t	6.67	4.51	
TSP emission	kg/t	3.59	2.72	
Investment for CS	10^6 RMB	0	130	
Capacity for CS	10^6 tpy	0.186	0.433	
Investment per TPY	Y/tpy		300	
Present capacity	10^6 tpy	22		

Calculated -- financial -- IRR 19.2 percent
Calculated payback inc construction time 10 years

BAU FORECAST		1990	2000	2010	
Capacity old wet	10^6 tpy	22.0	22.0	11.0	
Capacity new dry	10^6 tpy	0.0	0.0	11.0	
Energy old wet	10^3 tce/yr	5460.8	5460.8	2730.4	
Energy new dry	10^3 tce/yr	0.0	0.0	1865.3	
Total energy	10^3 tce/yr	5460.8	5460.8	4595.7	
Energy saved	10^3 tce/yr	0.0	.0	865.1	**
CO2	10^3 t/y	3614.4	3614.4	3054.5	
SO2	10^3 t/y	146.7	146.7	123.0	
TSP	10^3 t/y	79.0	79.0	69.4	
CO2 removal	10^3 t/y		.0	559.9	**
Investment	10^6 RMB		0.0	3301.0	
Invest CO2 removal	RMB per t/y		0	5896	**
Invest TCE saved	RMB per TCE/y		0	3816	**
ACCELERATED FORECAST					
Capacity old wet	10^6 tpy	22.0	22.0	0.0	
Capacity new dry	10^6 tpy	0.0	0.0	22.0	
Energy old wet	10^3 tce/yr	5460.8	5460.8	0.0	
Energy new dry	10^3 tce/yr	0.0	0.0	3730.5	
Total energy	10^3 tce/yr	5460.8	5460.8	3730.5	
Energy saved	10^3 tce/yr	0.0	.0	1730.3	**
CO2	10^3 t/y	3614.4	3614.4	2494.6	
SO2	10^3 t/y	146.7	146.7	99.2	
TSP	10^3 t/y	79.0	79.0	59.8	
CO2 removal	10^3 t/y		.0	1119.8	**
Investment	10^6 RMB		0.0	6602.0	
Invest CO2 removal	RMB per t/y		0	5896	**
Invest TCE saved	RMB per TCE/y		0	3816	**

NOTES

1 Wet process capacity is about 11% of 200 million tpy, say 22 mm tpy.

2 It is assumed that no conversions will be completed before 2000 but about half this capacity will be converted by 2010 under the BAU case. This means about 40-50 kilns.

3 It is assumed that all kilns -- say 100 -- could be converted by 2010 under the ACCEL case.

CASE STUDY ANALYSIS NUMBER B3 Vertical shaft kiln renovation

		Without project old plant	With project new plant		
Net energy use	kgCE/t	189	127		
CO2 emission	kg/t	110.90	80.54		
SO2 emission	kg/t	4.48	3.22		
TSP emission	kg/t	2.50	1.91		
Investment for CS	10^6 RMB	0	26.7		
Capacity for CS	10^6 tpy	0.510	0.650		
Investment per TPY	RMB/tpy		41		
Present capacity	10^6 tpy	50			
Calculated -- financial -- IRR			32.3	percent	
Calculated payback inc construction time			7	years	
BAU FORECAST		1990	2000	2010	
Capacity old	10^6 tpy	50.0	37.5	0.0	
Capacity renov.	10^6 tpy	0.0	12.5	50.0	
Energy old	10^3 tce/yr	9444	7083	0	
Energy renov.	10^3 tce/yr	0	1585	6341	
Total energy	10^3 tce/yr	9444	8668	6341	
Energy saved	10^3 tce/yr	0	776	3103	**
CO2	10^3 t/y	5545	5166	4027	
SO2	10^3 t/y	224	208	161	
TSP	10^3 t/y	125	118	96	
CO2 removal	10^3 t/y		380	1518	**
Investment	10^6 RMB		513	2053	
Invest CO2 removal	RMB per t/y		1352.5	1352.5	**
Invest TCE saved	RMB per TCE/y		661.6	661.6	**
ACCELERATED FORECAST					
Capacity old	10^6 tpy	50.0	32.5	0.0	
Capacity renov.	10^6 tpy	0.0	17.5	50.0	
Energy old	10^3 tce/yr	9444	6138	0	
Energy renov.	10^3 tce/yr	0	2219	6341	
Total energy	10^3 tce/yr	9444	8357	6341	
Energy saved	10^3 tce/yr	0	1086	3103	**
CO2	10^3 t/y	5545	5014	4027	
SO2	10^3 t/y	224	202	161	
TSP	10^3 t/y	125	115	96	
CO2 removal	10^3 t/y		531	1518	**
Investment	10^6 RMB		719	2053	
Invest CO2 removal	RMB per t/y		1352.5	1352.5	**
Invest TCE saved	RMB per TCE/y		661.6	661.6	**

NOTES

1 Shaft kilns represent about 150 mm tpy cement capacity, many being quite small. Many are very old and use outdated equipment.

2 It is assumed that about one third, say 50 mm tpy capacity, represents kilns that are worth renovating -- many will be too old to upgrade and may well be replaced by new plants.

3 For the BAU case, it is assumed that up to one quarter could be renovated by 2000 and the balance by 2010. This represents about 25 plants by 2000 and the full 100 or so by 2010.

4 In the ACCEL case, the renovation of 35% by 2000 is assumed -- 30-40 plants -- and the balance by 2010.

CASE STUDY ANALYSIS NUMBER L1 Black liquor recovery

		Without project	With project with BL recovery	
Net energy use	kgCE/t	532	348	
CO2 emission	kg/t	1054.70	422.35	
SO2 emission	kg/t	6.52	8.47	
TSP emission	kg/t	11.31	2.17	
Investment for CS	10^6 RMB	0	11.32	
Capacity for CS	10^6 tpy	0.017	0.017	
Investment per TPY	RMB/tpy		666	
Present capacity without bl recovery	10^6 tpy	1.2		
Calculated -- financial -- IRR			24.5 percent	
Calculated payback inc construction time			9 years	

BAU FORECAST		1990	2000	2010	
Capacity no rec	10^6 tpy	1.2	0.8	0.0	
Capacity with rec	10^6 tpy	0.0	0.4	1.2	
Energy no rec	10^3 tce/yr	638.4	425.6	0.0	
Energy with rec	10^3 tce/yr	0.0	139.2	417.6	
Total energy	10^3 tce/yr	638.4	564.8	417.6	
Energy saved	10^3 tce/yr	0.0	73.6	220.8	**
CO2	10^3 t/y	1265.6	1012.7	506.8	
SO2	10^3 t/y	7.8	8.6	10.2	
TSP	10^3 t/y	13.6	9.9	2.6	
CO2 removal	10^3 t/y		252.9	758.8	**
Investment	10^6 RMB		266.4	799.1	
Invest CO2 removal	RMB per t/y		1053	1053	**
Invest TCE saved	RMB per TCE/y		3619	3619	**

ACCELERATED FORECAST		1990	2000	2010	
Capacity no rec	10^6 tpy	1.2	0.6	0.0	
Capacity with rec	10^6 tpy	0.0	0.6	1.2	
Energy no rec	10^3 tce/yr	638.4	319.2	0.0	
Energy with rec	10^3 tce/yr	0.0	208.8	417.6	
Total energy	10^3 tce/yr	638.4	528.0	417.6	
Energy saved	10^3 tce/yr	0.0	110.4	220.8	**
CO2	10^3 t/y	1265.6	886.2	506.8	
SO2	10^3 t/y	7.8	9.0	10.2	
TSP	10^3 t/y	13.6	8.1	2.6	
CO2 removal	10^3 t/y		379.4	758.8	**
Investment	10^6 RMB		399.5	799.1	
Invest CO2 removal	RMB per t/y		1053	1053	**
Invest TCE saved	RMB per TCE/y		3619	3619	**

NOTES

1 The situation with respect to caustic recovery (black liquor recovery) may be summarised as follows:

	Wood base	Straw	Total
with rec.	800	400	1200
no rec.	100	1600	1700
	900	2000	2900

All figures refer to 10^3 tpy pulping capacit

2 Of the 1700 without recovery, systems for 500 are under construction. The potential is thus 1,200,000 tpy.

3 For the BAU case, it is assumed that all plants will be fitted with black liquor recovery systems by 2010 but only one third -- say 20 plants -- by 2000.

4 For the ACCEL case, half -- say 30 plants -- will be fitted with BL recovery by 2000.

5 It is assumed that all new pulping plants will automatically have BL recovery facilities built into the design.

6 Energy use and emission factors estimated as follows:

	without project	with project	
Net energy use	9043.13	5918.54	TCE/yr
CO2	17930	7180	tpy
SO2	110.90	144.00	tpy
TSP	192.25	36.81	tpy

To relate these to pulp produced, each figure was divided by 17000 -- the pulp production in tpy for the case study plant, Bostenghu Paper Mill, Kulle City, Xinjiang Autonomous Region.

		Without project	With project with cogen	
Net energy use	kgCE/t	2094	1691	
CO2 emission	kg/t	1363.4	1101.0	
SO2 emission	kg/t	67.0	54.1	
TSP emission	kg/t	0.0	0.0	
Investment for CS	10^6 RMB	0	48.52	
Capacity for CS	10^6 tpy	0.083	0.083	
Investment per TPY	RMB per tpy		585	
Present capacity with no cogeneration	10^6 tpy	2.4		
Calculated -- financial -- IRR			24.6 percent	
Calculated payback inc construction time			5 years	

BAU FORECAST		1990	2000	2010	
Capacity no cogen	10^6 tpy	2.4	1.9	0.0	
Capacity with cog	10^6 tpy	0.0	0.5	2.4	
Energy no cogen	10^3 tce/yr	5025.6	3978.6	0.0	
Energy with cogen	10^3 tce/yr	0.0	845.5	4058.4	
Total energy	10^3 tce/yr	5025.6	4824.1	4058.4	
Energy saved	10^3 tce/yr	0.0	201.5	967.2	**
CO2	10^3 t/y	3272.2	3141.0	2642.4	
SO2	10^3 t/y	160.8	154.4	129.8	
TSP	10^3 t/y	0.0	0.0	0.0	
CO2 removal	10^3 t/y		131.2	629.8	**
Investment	10^6 RMB		292.3	1403.0	
Invest CO2 removal	RMB per tpy		2228	2228	**
Invest TCE saved	RMB per TCE/y		1451	1451	**

ACCELERATED FORECAST					
Capacity no cogen	10^6 tpy	2.4	1.4	0.0	
Capacity with cog	10^6 tpy	0.0	1.0	2.4	
Energy no cogen	10^3 tce/yr	5025.6	2931.6	0.0	
Energy with cogen	10^3 tce/yr	0.0	1691.0	4058.4	
Total energy	10^3 tce/yr	5025.6	4622.6	4058.4	
Energy saved	10^3 tce/yr	0.0	403.0	967.2	**
CO2	10^3 t/y	3272.2	3009.8	2642.4	
SO2	10^3 t/y	160.8	147.9	129.8	
TSP	10^3 t/y	0.0	0.0	0.0	
CO2 removal	10^3 t/y		262.4	629.8	**
Investment	10^6 RMB		584.6	1403.0	
Invest CO2 removal	RMB per tpy		2228	2228	**
Invest TCE saved	RMB per TCE/y		1451	1451	**

NOTES

1 Of the 5000+ paper plants in China, only 60 or so have their own power plant. It is estimated that 80 new mills could install 300 MW generating capacity (cogeneration), average size say 4 MW.

2 Based on 80 mills of average size 30,000 tpy paper products -- which corresponds approximately to 4 MW electrical load -- the capacity of mills with the potential to install cogeneration is estimated to be 2.4 mm tpy paper.

3 It is assumed that all these mills will have installed such systems by 2010 and that all new mills of comparable size will install cogeneration.

4 For the BAU case, it is assumed that 15 to 20 mills will have installed cogeneration by 2000, representing say 0.5 mm tpy capacity.

5 For the ACCEL case, it is assumed 30-35 mills will have installed cogeneration by 2000, a capacity of 1 mm tpy paper.

6 Energy and emissions factors derived as follows:

		without project	with project
Energy*	TCE/yr	173825	140345
CO2	tpy	113160	91365
SO2	tpy	5562	4491

To relate these to paper production, these figures were divided by 83000, the paper output in tpy of the case study plant, Yalujiang Paper Mill, Dandong City, Liaoning Province.

* Note that the energy and emissions associated with the electricity export from the cogeneration system are included as energy and emissions for the "without" case, as the electricity would have been generated elsewhere.

CASE STUDY ANALYSIS NUMBER T1 Cogeneration in textile mill

		Without project no cogen	With project with cogen		
Net energy use	kgCE/mm M	375600	315000		
CO2 emission	kg/mm M	245600	201485		
SO2 emission	kg/mm M	10209	8738		
TSP emission	kg/mm M	4768	2960		
Investment for CS	10^6 RMB	0	7.13 incremental		
Capacity for CS	10^6 M/y	60.0	60.0		
Investment per M	RMB per M/y		0.119		
Present capacity	10^6 M/y	30000			
Calculated -- financial -- IRR			37.6 percent		
Calculated payback inc construction time			6 years		
BAU FORECAST		1990	2000	2010	
Capacity no cogen	10^6 M/y	30000	25200	6000	
Cap. with cogen	10^6 M/y	0	4800	24000	
Energy no cogen	10^3 tce/yr	11268.0	9465.1	2253.6	
Energy with cogen	10^3 tce/yr	0.0	1512.0	7560.0	
Total energy	10^3 tce/yr	11268.0	10977.1	9813.6	
Energy saved	10^3 tce/yr	0.0	290.9	1454.4	**
CO2	10^3 t/y	7368.0	7156.2	6309.2	
SO2	10^3 t/y	306.3	299.2	271.0	
TSP	10^3 t/y	143.0	134.4	99.6	
CO2 removal	10^3 t/y		211.8	1058.8	**
Investment	10^6 RMB		570.4	2852.0	
Invest CO2 removal	RMB per tpy		2694	2694	**
Invest TCE saved	RMB per TCE/y		1961	1961	**
ACCELERATED FORECAST					
Capacity no cogen	10^6 M/y	30000	22800	3000	
Cap. with cogen	10^6 M/y	0	7200	27000	
Energy no cogen	10^3 tce/yr	11268.0	8563.7	1126.8	
Energy with cogen	10^3 tce/yr	0.0	2268.0	8505.0	
Total energy	10^3 tce/yr	11268.0	10831.7	9631.8	
Energy saved	10^3 tce/yr	0.0	436.3	1636.2	**
CO2	10^3 t/y	7368.0	7050.4	6176.9	
SO2	10^3 t/y	306.3	295.7	266.6	
TSP	10^3 t/y	143.0	130.0	94.2	
CO2 removal	10^3 t/y		317.6	1191.1	**
Investment	10^6 RMB		855.6	3208.5	
Invest CO2 removal	RMB per tpy		2694	2694	**
Invest TCE saved	RMB per TCE/y		1961	1961	**

NOTES

1 The example plant chosen for the case study analysis produces about 60 million meters per year of fabric and there are about 500 similar plants. This represents a capacity of 30,000 million m/y.

2 For the BAU case, it is assumed that about 80 plants (capacity 4,800 million m/y) will have installed cogeneration by 2000 and 400 plants (24,000 mm m/y or 80% of the potential) by 2010.

3 For the ACCEL case, 120 plants are assumed to have cogeneration by 2000 (7,200 mm m/y or 24%) and 90% by 2010 (27,000 mm m/y).

4 Energy and emission factors were derived from the case study data as follows:

		without project	with project
Energy	TCE/yr	22534	18902
CO2	tpy	14739	12089
SO2	tpy	613	524
TSP	tpy	286	178

These figures were then divided by 60 million metres, the annual output of the case study plnt (Yangzhou Dyeing and Printing Mill, Jiangsu Province) in order to relate changes in energy and emissions to textile production for sector aggregation purposes.

CASE STUDY ANALYSIS NUMBER T2 NaOH recovery, textiles sector

		Without project no recovery	With project with recov
Net energy use	kgCE/t	42974	32835
CO2 emission	kg/mm metre	28004	21546
SO2 emission	kg/mm metre	0	4
TSP emission	kg/mm metre	336	259
Investment for CS	10^6 RMB	0	2.01
Capacity for CS	10^6 m/y	60.0	60.0
Investment per TPY	RMB per m/y		0.034
Present capacity	10^6 m/y	30000	

Calculated -- financial -- IRR 57.9 percent
Calculated payback inc construction time 3 years

BAU FORECAST		1990	2000	2010	
Capacity no rec	10^6 m/y	30000	25000	3000	
Capacity with rec	10^6 m/y	0	5000	27000	
Energy no rec	10^3 tce/yr	1289.2	1074.4	128.9	
Energy with rec	10^3 tce/yr	0.0	164.2	886.5	
Total energy	10^3 tce/yr	1289.2	1238.5	1015.5	
Energy saved	10^3 tce/yr	0.0	50.7	273.8	**
CO2	10^3 t/y	840.1	807.8	665.8	
SO2	10^3 t/y	0.0	.0	0.1	
TSP	10^3 t/y	10.1	9.7	8.0	
CO2 removal	10^3 t/y		32.3	174.4	**
Investment	10^6 RMB		167.5	904.5	
Invest CO2 removal	RMB per t/y		5187	5187	
Invest TCE saved	RMB per TCE/y		3304	3304	**

ACCELERATED FORECAST					
Capacity no rec	10^6 m/y	30000	21000	0	
Capacity with rec	10^6 m/y	0	9000	30000	
Energy no rec	10^3 tce/yr	1289.2	902.5	0.0	
Energy with rec	10^3 tce/yr	0.0	295.5	985.1	
Total energy	10^3 tce/yr	1289.2	1198.0	985.1	
Energy saved	10^3 tce/yr	0.0	91.3	304.2	**
CO2	10^3 t/y	840.1	782.0	646.4	
SO2	10^3 t/y	0.0	.0	0.1	
TSP	10^3 t/y	10.1	9.4	7.8	
CO2 removal	10^3 t/y		58.1	193.7	**
Investment	10^6 RMB		301.5	1005.0	
Invest CO2 removal	RMB per t/y		5187	5187	**
Invest TCE saved	RMB per TCE/y		3304	3304	**

NOTES

1 As for case study T1, the estimated capacity of plants without caustic soda recovery is (500 x 60) or 30,000 million m/y.

2 For the BAU case, about 80 plants are assumed able to install recovery systems by 2000 (capacity 5,000 mm m/y) and 450 plants, say 90%, by 2010 (capacity 27,000 mm m/y).

3 For the ACCEL case, 150 plants are assumed to install recovery systems by 2000 (capacity 9000 mm m/y) and all plants, about 500, by 2010.

4 For the case study at Yangzhou Dyeing and Printing Mill, the incremental investment was 2.01 million RMB, the difference between the new investment of 3.89 mm and the amount needed to keep the old system operating (1.88 million for tanks, controls, etc).

5 Energy and emissions factors were derived as follows:

		without project	with project
Energy	TCE/yr		
in plant		25.41	1002.82
for caustic		2553.04	967.26
total		2578.45	1970.08
CO2	tpy	1680.25	1292.78
SO2	tpy	0.00	0.23
TSP	tpy	20.16	15.51

These figures were divided by 60 million metres, the annual output of the Yangzhou plant, to relate changes in energy use and emissions to textile production.

CASE STUDY ANALYSIS NUMBER T3 Energy management

		Without project	With project computerised
Net energy use	kgCE/mm m	70687	63618
CO2 emission	kg/mm metre	46917	42225
SO2 emission	kg/mm metre	1895	1706
TSP emission	kg/mm metre	1053	948
Investment for CS	10^6 RMB	0	1.5
Capacity for CS	10^6 m/y	60.0	60.0
Investment per TPY	RMB per m/y		0.025
Present capacity	10^6 m/y	30000	

NOTES

1 It is assumed that about 10% of energy can be saved by computerising the production systems and adding new meters.

BAU FORECAST		1990	2000	2010	
Capacity existing	10^6 m/y	30000	22500	0	
Capacity computer.	10^6 m/y	0	7500	30000	
Energy existing	10^3 tce/yr	2120.6	1590.5	0.0	
Energy computer.	10^3 tce/yr	0.0	477.1	1908.5	
Total energy	10^3 tce/yr	2120.6	2067.6	1908.5	
Energy saved	10^3 tce/yr	0.0	53.0	212.1	**
CO2	10^3 t/y	1407.5	1372.3	1266.8	
SO2	10^3 t/y	56.9	55.4	51.2	
TSP	10^3 t/y	31.6	30.8	28.4	
CO2 removal	10^3 t/y		35.2	140.8	**
Investment	10^6 RMB		187.5	750.0	
Invest CO2 removal	RMB per t/y		5328	5328	**
Invest TCE saved	RMB per TCE/y		3537	3537	**

ACCELERATED FORECAST					
Capacity existing	10^6 m/y	30000	18000	0	
Capacity computer.	10^6 m/y	0	12000	30000	
Energy existing	10^3 tce/yr	2120.6	1272.4	0.0	
Energy computer.	10^3 tce/yr	0.0	763.4	1908.5	
Total energy	10^3 tce/yr	2120.6	2035.8	1908.5	
Energy saved	10^3 tce/yr	0.0	84.8	212.1	**
CO2	10^3 t/y	1407.5	1351.2	1266.8	
SO2	10^3 t/y	56.9	54.6	51.2	
TSP	10^3 t/y	31.6	30.3	28.4	
CO2 removal	10^3 t/y		56.3	140.8	**
Investment	10^6 RMB		300.0	750.0	
Invest CO2 removal	RMB per t/y		5328	5328	**
Invest TCE saved	RMB per TCE/y		3537	3537	**

CASE STUDY ANALYSIS NUMBER CH1 Medium size ammonia renovation

		Without project (old plants)	With project (renovated)	
Net energy use	kgCE/t	2135	1723	
CO2 emission	kg/t	1437.20	1126.06	
SO2 emission	kg/t	56.50	46.88	
TSP emission	kg/t	36.35	21.66	
Investment for CS	10^6 RMB	0	370.69	
Capacity for CS	10^6 tpy	0.080	0.180	
Investment per TPY	RMB/tpy		2059	
Present capacity	10^6 tpy	1.5		
Calculated -- financial -- IRR			19.5 percent	
Calculated payback inc construction time			10 years	

		1990	2000	2010	
BAU FORECAST					
Capacity old	10^6 tpy	1.5	1.5	1.5	
Capacity renov.	10^6 tpy	0.0	0.0	0.0	
Energy old	10^3 tce/yr	3203.1	3203.1	3203.1	
Energy renov.	10^3 tce/yr	0.0	0.0	0.0	
Total energy	10^3 tce/yr	3203.1	3203.1	3203.1	
Energy saved	10^3 tce/yr	0.0	.0	.0	**
CO2	10^3 t/y	2155.8	2155.8	2155.8	
SO2	10^3 t/y	84.8	84.8	84.8	
TSP	10^3 t/y	54.5	54.5	54.5	
CO2 removal	10^3 t/y		.0	.0	**
Investment	10^6 RMB		.0	0.0	
Invest CO2 removal	RMB per t/y		0	0	**
Invest TCE saved	RMB per TCE/y		0	0	**
ACCELERATED FORECAST					
Capacity old	10^6 tpy	1.5	1.2	0.6	
Capacity renov.	10^6 tpy	0.0	0.3	0.9	
Energy old	10^3 tce/yr	3203.1	2562.5	1281.2	
Energy renov.	10^3 tce/yr	0.0	516.9	1550.8	
Total energy	10^3 tce/yr	3203.1	3079.4	2832.0	
Energy saved	10^3 tce/yr	0.0	123.7	371.0	**
CO2	10^3 t/y	2155.8	2062.5	1875.8	
SO2	10^3 t/y	84.8	81.9	76.1	
TSP	10^3 t/y	54.5	50.1	41.3	
CO2 removal	10^3 t/y		93.3	280.0	**
Investment	10^6 RMB		617.8	1853.5	
Invest CO2 removal	RMB per t/y		6619	6619	**
Invest TCE saved	RMB per TCE/y		4995	4995	**

NOTES

1 There are about 56 medium size plants, typical capacity 80,000 tpy ammonia, of which 34 use coal and the others oil/gas.

2 The 34 plants represent up to 3 mm tpy capacity but perhaps half will not be renovated -- rather, new plants will be built, much larger, to replace them. Assume therefore that the realistic maximum capacity for renovation is 1.5 mm tpy (say 15 to 20 plants).

3 For the BAU case, assume no plants at all will be renovated -- IRR not very attractive.

4 For the ACCEL case, assume up to 20% of capacity renovated by 2000, say 4-5 plants, and up to 60% by 2010 (10-12 plants).

CASE STUDY ANALYSIS NUMBER CH2 Small ammonia renovation and waste heat recovery

		Without project old plant	With project with WHR		
Net energy use	kgCE/t	2175	1899		
CO2 emission	kg/t	1451.15	1271.03		
SO2 emission	kg/t	58.05	50.52		
TSP emission	kg/t	34.10	30.70		
Investment for CS	10^6 RMB	0	3.01		
Capacity for CS	10^6 tpy	0.017	0.019 ammonia		
Investment per TPY	RMB/tpy		158		
Present capacity	10^6 tpy	7.5			
Calculated -- financial -- IRR			71.4 percent		
Calculated payback inc construction time			3 years		
BAU FORECAST		1990	2000	2010	
Capacity old	10^6 tpy	7.5	6.0	0.0	
Capacity renov.	10^6 tpy	0.0	1.5	7.5	
Energy old	10^3 tce/yr	16314.0	13051.2	0.0	
Energy renov.	10^3 tce/yr	0.0	2848.7	14243.6	
Total energy	10^3 tce/yr	16314.0	15899.9	14243.6	
Energy saved	10^3 tce/yr	0.0	414.1	2070.4	**
CO2	10^3 t/y	10883.6	10613.4	9532.7	
SO2	10^3 t/y	435.4	424.1	378.9	
TSP	10^3 t/y	255.8	250.7	230.3	
CO2 removal	10^3 t/y		270.2	1350.9	**
Investment	10^6 RMB		237.6	1188.2	
Invest CO2 removal	RMB per t/y		880	880	**
Invest TCE saved	RMB per TCE/y		574	574	**
ACCELERATED FORECAST					
Capacity old	10^6 tpy	7.5	4.5	0.0	
Capacity renov.	10^6 tpy	0.0	3.0	7.5	
Energy old	10^3 tce/yr	16314.0	9788.4	0.0	
Energy renov.	10^3 tce/yr	0.0	5697.4	14243.6	
Total energy	10^3 tce/yr	16314.0	15485.8	14243.6	
Energy saved	10^3 tce/yr	0.0	828.2	2070.4	**
CO2	10^3 t/y	10883.6	10343.3	9532.7	
SO2	10^3 t/y	435.4	412.8	378.9	
TSP	10^3 t/y	255.8	245.6	230.3	
CO2 removal	10^3 t/y		540.4	1350.9	**
Investment	10^6 RMB		475.3	1188.2	
Invest CO2 removal	RMB per t/y		880	880	**
Invest TCE saved	RMB per TCE/y		574	574	**

NOTES

1 Production by small plants (under 45,000 tpy ammonia) represents over half of national ammonia production. Over 1000 such enterprises, over 900 using anthracite.

2 Ammonia production by such small plants is thus about 11 mm tpy. Not all plants will be suitable for renovation -- many are likely to be replaced by new large scale plants. Assume therefore that about two thirds of capacity -- 7.5 mm tpy -- is the full potential.

3 For BAU case, assume about 100 plants renovated by 2000, while 200 or more are renovated under the ACCEL case.

4 By 2010, assume all plants renovated -- about 500 in total.

CASE STUDY ANALYSIS NUMBER CH3 New membrane process at NaOH plant

		Without project old plant	With project new membrane	
Net energy use	kgCE/t	1899	1018	
CO2 emission	kg/t	1316.22	729.14	
SO2 emission	kg/t	48.79	25.25	
TSP emission	kg/t	41.02	27.37	
Investment for CS	10^6 RMB	0	52.14	incremental
Capacity for CS	10^6 tpy	0.020	0.020	
Investment per TPY	RMB/tpy		2607	
Present capacity	10^6 tpy	4		
Calculated -- financial -- IRR			29.4	percent
Calculated payback inc construction time			6	years

		1990	2000	2010	
BAU FORECAST					
Capacity old	10^6 tpy	3.0	3.0	2.7	
Capacity new	10^6 tpy	0.0	0.0	0.3	
Energy old	10^3 tce/yr	5696.9	5696.9	5127.2	
Energy new	10^3 tce/yr	0.0	0.0	305.4	
Total energy	10^3 tce/yr	5696.9	5696.9	5432.6	
Energy saved	10^3 tce/yr	0.0	.0	264.3	**
CO2	10^3 t/y	3948.7	3948.7	3772.5	
SO2	10^3 t/y	146.4	146.4	139.3	
TSP	10^3 t/y	123.1	123.1	119.0	
CO2 removal	10^3 t/y		.0	176.1	**
Investment	10^6 RMB		0.0	782.1	
Invest CO2 removal	RMB per t/y		0	4441	**
Invest TCE saved	RMB per TCE/y		0	2959	**
ACCELERATED FORECAST					
Capacity old	10^6 tpy	3.0	2.4	1.5	
Capacity new	10^6 tpy	0.0	0.6	1.5	
Energy old	10^3 tce/yr	5696.9	4557.6	2848.5	
Energy new	10^3 tce/yr	0.0	610.7	1526.8	
Total energy	10^3 tce/yr	5696.9	5168.3	4375.3	
Energy saved	10^3 tce/yr	0.0	528.7	1321.7	**
CO2	10^3 t/y	3948.7	3596.4	3068.0	
SO2	10^3 t/y	146.4	132.2	111.1	
TSP	10^3 t/y	123.1	114.9	102.6	
CO2 removal	10^3 t/y		352.2	880.6	**
Investment	10^6 RMB		1564.2	3910.5	
Invest CO2 removal	RMB per t/y		4441	4441	**
Invest TCE saved	RMB per TCE/y		2959	2959	**

NOTES

1 About 150-200 plants similar to the case study example have the potential for modification to membrane technology.

2 Assume 150 plants, each with capacity 20,000 tpy caustic soda. The full potential is thus 3 mm tpy.

3 For the BAU case, assume no modifications until after 2000, when only about 10% will be modified.

4 For the ACCEL case, assume 20% -- say 30 plants -- modified by 2000 and 50% or say 70-80 plants by 2010.

CASE STUDY ANALYSIS NUMBER E1 High efficiency motors

		Without project standard motors	With project high eff motors		
Energy savings	MWh/MW installed		90		
CO2 emission	kg/MWh	290.00	290.00	emission factors	
SO2 emission	kg/MWh	10.00	10.00	kg/MWh	
TSP emission	kg/MWh	11.00	11.00		
Investment for CS	10^6 RMB	0	240		
Capacity for CS	MW manufact/yr		5000		
Investment per MW	RMB per annual MW manuf.		48000		
Present capacity	MW manuf/yr	0	0		
Final capacity	MW manuf/yr	0	60000		
Calculated -- financial -- IRR			xxxxx	percent	
Calculated payback inc construction time			xxxxx	years	

		1990	2000	2010	
BAU FORECAST					
HE motors made	MW/yr	0	2500	15000	
Energy saved	10^6 kWh	0	225.0	1350.0	
eq 10^3 TCE/yr at	3200 kcal/kWh		102.9	617.1	**
CO2 reduction	10^3 t/y	0	65.3	391.5	**
SO2 reduction	10^3 t/y	0	2.3	13.5	
TSP reduction	10^3 t/y	0	2.5	14.9	
Investment	10^6 RMB		120.0	720.0	
Invest CO2 removal	RMB per t/y		1839	1839	**
Invest TCE saved	RMB per TCE/y		1167	1167	**
ACCELERATED FORECAST					
HE motors made	MW/yr	0	5000	25000	
Energy saved	10^6 kWh	0	450.0	2250.0	
eq 10^3 TCE/yr at	3200 kcal/kWh		205.7	1028.6	**
CO2 reduction	10^3 t/y	0	130.5	652.5	**
SO2 reduction	10^3 t/y	0	4.5	22.5	
TSP reduction	10^3 t/y	0	5.0	24.8	
Investment	10^6 RMB		240.0	1200.0	
Invest CO2 removal	RMB per t/y		1839	1839	**
Invest TCE saved	RMB per TCE/y		1167	1167	**

NOTES

1 Investment figure shown is for motor manufacture only and does not relate to the consumers/purchasers of motors.

2 The case study estimates savings of 450,000 MWh for 5000 MW installed motors (90 MWh per MW).

3 Motor population is about 330,000 MW. To replace existing motors with high efficiency units, it is estimated that 5000 MW of new motors will be needed (Directive GB 12497 on "The economic operation of 3-phase induction motors"). A further 6500 MW will be needed for new applications.

4 It is assumed sales of high efficiency motors will reach half the 5000 MW (2-3 plants) under BAU conditions and the full amount if accelerated (say 5 new or renovated motor manufacturing plants). By 2010, outputs could be 3 to 5 times that amount -- to meet replacement and new application demands.

CASE STUDY ANALYSIS NUMBER E2 Variable speed motors

		Without project standard motors	With project var speed motors	
Energy savings	MWh/MW installed		540	
CO2 emission	kg/MWh	290.00	290.00	emission factors
SO2 emission	kg/MWh	10.00	10.00	kg/MWh
TSP emission	kg/MWh	11.00	11.00	
Investment for CS	10^6 RMB	0	100	
Capacity for CS	MW manufact/yr		3000	
Investment per MW	RMB/annual MW manufact		33333	
Present capacity	MW manuf/yr	0	0	
Final capacity	MW manuf/yr	0	12000	

Calculated -- financial -- IRR	xxxxxxx	percent
Calculated payback inc construction time	xxxxxxx	years

BAU FORECAST		1990	2000	2010	
VS motors made	MW/yr	0	1000	3000	
Energy saved	10^6 kWh	0	540.0	1620.0	
eq 10^3 TCE/yr at	3200 kcal/kWh		246.9	740.6	xx
CO2 reduction	10^3 t/y	0	156.6	469.8	xx
SO2 reduction	10^3 t/y	0	5.4	16.2	
TSP reduction	10^3 t/y	0	5.9	17.8	
Investment	10^6 RMB		33.3	100.0	
Invest CO2 removal	RMB per t/y		213	213	xx
Invest TCE saved	RMB per TCE/y		135	135	xx

ACCELERATED FORECAST					
VS motors made	MW/yr	0	1500	4500	
Energy saved	10^6 kWh	0	810.0	2430.0	
eq 10^3 TCE/yr at	3200 kcal/kWh		370.3	1110.9	xx
CO2 reduction	10^3 t/y	0	234.9	704.7	xx
SO2 reduction	10^3 t/y	0	8.1	24.3	
TSP reduction	10^3 t/y	0	8.9	26.7	
Investment	10^6 RMB		50.0	150.0	
Invest CO2 removal	RMB per t/y		213	213	xx
Invest TCE saved	RMB per TCE/y		135	135	xx

NOTES

1 Market for VS motors estimated at say 1500 MW for replacements and 1500 MW for new applications each year.

2 Investment data are for motor manufacture only, not for the users/customers.

3 From data for Zhejiang and Shenyang motor manufacturing plants, it is estimated that 3000 MW motor capacity needs an investment of 3000 million RMB (say 7-10 plants).

4 Total annual savings are estimated to be about 1.62 million MWh (20% savings, 4500 hrs., load 60%) for 3000 MW installed capacity.

5 It is assumed the installed capacity will reach 1/3 (BAU) or 1/2 (ACCEL) of the 3000 MW by 2000 and the full amount (BAU) or even 50% more (ACCEL) by 2010.

CASE STUDY ANALYSIS NUMBER E3 Electric motor repair centres

		Without project ord repairs	With project repair centre	
Energy savings	MWh/MW rep	0	48	
CO_2 emission	kg/MWh	290.00	290.00	emission factors
SO_2 emission	kg/MWh	10.00	10.00	kg/MWh
TSP emission	kg/MWh	11.00	11.00	
Investment for CS	10^6 RMB	0	7.123	
Capacity for CS	MW rep/yr	0	600	
Investment per MW	RMB/annual MW repaired		11872	
Present capacity	MW rep/yr	0	0	
Final capacity	MW rep/yr	0	10000	
Calculated IRR			45	percent
Calculated payback inc construction time			2 to 3	years

BAU FORECAST		1990	2000	2010
Repair capacity	MW/yr	0	2500	5000
Energy saved	10^6 kWh/y	0	120.0	240.0
equiv 10^3 TCE at	3200 kcal/kWh		54.9	109.7
CO_2 reduction	10^3 t/y	0	34.8	69.6
SO_2 reduction	10^3 t/y	0	1.2	2.4
TSP reduction	10^3 t/y	0	1.3	2.6
Investment	million Y		29.7	59.4
Invest CO_2 removal	RMB per t/y		853	853
Invest TCE saved	RMB per TCE/y		541	541

ACCELERATED FORECAST				
Repair capacity	MW/yr	0	3500	8000
Energy saved	10^6 kWh/y	0	168.0	384.0
equiv 10^3 TCE at	3200 kcal/kWh		76.8	175.5
CO_2 reduction	10^3 t/y	0	48.7	111.4
SO_2 reduction	10^3 t/y	0	1.7	3.8
TSP reduction	10^3 t/y	0	1.8	4.2
Investment	million Y		41.6	95.0
Invest CO_2 removal	RMB per t/y		853	853
Invest TCE saved	RMB per TCE/y		541	541

NOTES

1 About 10,000 MW motors need repair each year, of which 5,000 MW need rewinding.

2 Savings estimate is based on 2% efficiency improvement:

4000 hrs × 0.02 × 0.6 × 5000 = 240,000
load MW MWh/year

240,000 / 5000 = 48 MWh/MW repaired

3 Investment based on Shanghai motor plant, 1.123 million RMB for 600 MW annual repair capacity.

4 For BAU, it is assumed that 1/2 the repair capacity (4-5 plants) are in place by 2000 and the full 5000 MW by 2010.

5 For ACCEL case, it is assumed 70% in place by 2000 and a total of 8000 MW by 2010.

CASE STUDY ANALYSIS NUMBER E4 Steam traps

		Without project	With project more traps		
Energy savings	TCE/trap		1		
CO2 emission	kg/TCE	651.00	651.00	emission factors	
SO2 emission	kg/TCE	27.30	27.30	kg/TCE	
TSP emission	kg/TCE	12.00	12.00		
Investment for CS	10^6 RMB	0	15.6		
Capacity for CS	10^6 traps/yr		0.188		
Investment	Y/annual trap manufact		83		
Calculated -- financial -- IRR			xxxxx	percent	
Calculated payback inc construction time			xxxxx	years	
BAU FORECAST		1990	2000		2010
Steam traps made	10^6 per yr	0	2		10
Energy saved	10^3 TCE/y	0	2000.0		10000.0
CO2 reduction	10^3 t/y	0	1302.0		6510.0
SO2 reduction	10^3 t/y	0	54.6		273.0
TSP reduction	10^3 t/y	0	24.0		120.0
Investment	10^6 RMB		166.0		829.8
Invest CO2 removal	RMB per t/y		127		127
Invest TCE saved	RMB per TCE/y		83		83
ACCELERATED FORECAST					
Steam traps made	million/yr	0	4		10
Energy saved	10^3 TCE/y	0	4000.0		10000.0
CO2 reduction	10^3 t/y	0	2604.0		6510.0
SO2 reduction	10^3 t/y	0	109.2		273.0
TSP reduction	10^3 t/y	0	48.0		120.0
Investment	10^6 RMB		331.9		829.8
Invest CO2 removal	RMB per t/y		127		127
Invest TCE saved	RMB per TCE/y		83		83

NOTES

1 A shortage of about 12 million traps was identified in the case study report.

2 Added capacity at the Yangzhou Valve Factory is expected to be 188,000 traps per year for an investment of 15.6 million RMB. Investment shown is for trap manufacture and has no relation to the trap purchaser.

3 Savings using good quality traps was estimated as follows:

* Duty say 0.2 t/h steam per trap.
* Savings say 1% or 0.002 t/h, equivalent to say 10 tpy steam or 1 TCE per year per trap.

4 For BAU, assume additional 10 million traps per year will be made, 2 million/y (say 10 new or upgraded plants) by 2000 and all (50 plants) by 2010.

5 For accel. case, assume 4 million traps/y by 2000 (up to 20 plants).