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China
Renewable Energy for Electric Power

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Asia Alternative Energy Unit (ASTAE)
Asia Technical Department
East Asia and Pacific Regional Office

Power Development, Efficiency
and Household Fuels Division (IENPD)
Industry and Energy Department
Finance and Private Sector Development

Document of the World Bank

CURRENCY EQUIVALENTS
(As of December 1, 1995)

Current Unit = Yuan (Y)
$1.00 = Y 8.3
Y 1.00 = $0.12

FISCAL YEAR

January 1 - December 31

WEIGHTS AND MEASURES

km	=	Kilometer (=0.62 miles)
kWh	=	Kilowatt hour (=860.42 kcal)
MWh	=	Megawatt hour (=1,000 kWh)
GWh	=	Gigawatt hour (=1,000,000 kilowatt hours)
TWh	=	Terawatt hour (=1,000,000,000 kilowatt hours)
kW	=	Kilowatt (=1,000 watts)
GW	=	Gigawatt (=1,000,000,000 watts)
MW	=	Megawatt (=1,000,000 watts)
kV	=	Kilovolt (1,000 volts)

ABBREVIATIONS AND ACRONYMS

BOO	-	Build, Own and Operate
BOT	-	Build, Own and Transfer
EIRR	-	Economic Internal Rate of Return
ESMAP	-	Energy Sector Management Assistance Programme
FIRR	-	Financial Internal Rate of Return
FIRREQ	-	Financial Internal Rate of Return on Equity
GEF	-	Global Environment Facility
GOC	-	Government of China
IPP	-	Independent Power Producer
IREDP	-	Integrated Rural Energy Development Program
ISCCS	-	Integrated Solar Combined Cycle Systems
LEC	-	Levelized Energy Cost
LOLP	-	Loss of Load Probability
MOA	-	Ministry of Agriculture
MOEP	-	Ministry of Electric Power
MOF	-	Ministry of Finance
MOWR	-	Ministry of Water Resources
NEPA	-	National Environmental Protection Agency
NFFO	-	Nonfossil Fuel Obligation
NPV	-	Net Present Value
PV	-	Photovoltaics
SEGS	-	Solar Electric Generating Stations
SETC	-	State Economic and Trade Commission
SHS	-	Solar Home Systems
SHP	-	Small Hydropower
SPC	-	State Planning Commission
SSTC	-	State Science and Technology Commission
UNDP	-	United Nations Development Programme
VAT	-	Value Added Tax
VAAT	-	Value Added Addition Tax
Wp	-	Watt-peak

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ANNEXES

TABLES IN TEXT

PREFACE

This report is the main output of a study executed organized jointly by the World Bank and the Government of China (GOC), and carried out by a group of Chinese and international experts (see the following page). The study identifies priorities and strategies for power-related renewable energy development in China. It complements a parallel study on thermal applications of renewable energy completed by GOC, with assistance from the Global Environment Facility (GEF). Together, the two studies provide a comprehensive assessment of renewable energy development priorities in China. The principal GOC agency coordinating both studies was the State Economic and Trade Commission (SETC). The studies were completed between July 1995 and June 1996.

On the Chinese side, a study coordinating committee composed of officials from various agencies was chaired by Zhao Jiarong, Deputy Director, Resources Conservation and Comprehensive Utilization Department, SETC. In addition, three working groups were formed by SETC: a technical group, an economic and financial group, and a policy and institutions group. The working groups also had memberships from various agencies and were coordinated by Zhu Junsheng, Division Chief for Renewable Energy, SETC; Liu Hongpeng, Deputy Division Chief, SETC; and Li Junfeng, Assistant Director, Energy Research Institute, State Planning Commission (SPC).

On the World Bank side, Anil Cabraal of the Asia Alternative Energy Unit (ASTAE) and Ernesto Terrado of the Power, Development and Household Fuels Division of the Industry and Energy Department (IENPD) were the co-task managers of the study. Robert Taylor, of the Infrastructure Operations Division of the China and Mongolia Department (EA2IN), provided coordination. The principal author of the report was Susan Bogach (ASTAE). Three international consultants were commissioned by the Bank for specific substudies: Robert Vernstrom, utility economist (avoided cost analysis); Rick Allis, geothermal expert, and Robert Chronowski, bagasse expert.

Under a special cooperative arrangement with the Bank, the US National Renewable Energy Laboratory (NREL) provided the services of three experts to assist in the main mission of the study: Brian Parsons, Project Manager, Wind Applications; Ralph Overend, Principal Scientist, Industrial Technologies Division (Biomass); and Dave Renne, Program Manager, Resource Assessment.

The study was made possible by substantial grant funding from the Netherlands Directorate General for International Cooperation (DGIS). The study also benefited from support provided by the Swedish International Development Agency (SIDA), the UNDP Energy and Atmospheric Programme, and the United States Department of Energy (USDOE).

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In addition, all the coordinating group members are also members of the Policy Group.

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EXECUTIVE SUMMARY

Introduction

1. In working toward sustainable economic development, the Government of China (GOC) faces major challenges. These include reducing reliance on coal with its associated adverse environmental impacts, and providing energy to the 80 to 100 million poor people living mainly in remote areas of the north and west.

2. Consequently, GOC is giving increased attention to renewable energy as a means of providing least-cost electricity to these remote areas, and, in the longer term, as a means of diversifying energy sources and curbing growth in pollution from coal plants. In 1995, the State Planning Commission (SPC), the State Science and Technology Commission (SSTC) and the State Economic and Trade Commission (SETC) jointly formulated a "Program of New and Renewable Energy Development, 1996-2010," and an implementation plan for the Ninth Five-Year Plan. The Electricity Law, passed in December 1995, also supports the development of renewable energy.

3. The present study was organized jointly by GOC and the World Bank and carried out by a team of Chinese and international experts. It identifies priorities for power-related renewable energy development in China. The study includes assessments of the *economic and financial viability* of renewable energy for power technologies, a review of *institutional and policy issues* affecting their development and an outline of *priorities for investment and technical assistance* support. The study covers both grid-connected and off-grid applications of renewable energy for power. GOC, with assistance from the Global Environment Facility (GEF), completed a complementary study of direct thermal applications of renewable energy. Together, the two studies provide a comprehensive assessment of renewable energy development priorities in China.

Status of Power-Related Renewable Energy Development in China

4. China has a rich renewable energy resource base. Wind resources at windfarm sites are "world class," superior to commercial windfarm sites in the United States and India. National wind resource potential exceeds 250 gigawatts (GW). Solar radiation is excellent, particularly in the northwestern parts of the country. Hydro, geothermal and biomass resources are abundant in some provinces. However, only small hydropower is fully commercial in China, with an installed capacity of 15 GW in 1993, 8 percent of the

total national generating capacity.[1] Small wind generators are commercial on a lesser scale, with over 140,000 in use, and a total capacity of 17 MW.

5. With the above exceptions, development of renewable energy for power has been on a research and pilot demonstration scale. At the end of 1994, China had 14 grid-connected windfarm sites with a total installed capacity of 30 MW. While there is a limited domestic manufacturing base for small wind turbines, there is no local production capacity for turbines of 200 kilowatts (kW) and larger. Photovoltaic (PV) module manufacturing capacity in China is 5 MW, although much of this capacity does not meet modern international standards and actual production in 1994 was only 1.4 MW. There were about 3 MW of solar photovoltaic systems in use in China at end 1994, of which about a third was in dispersed household systems. Similarly, there are only 30 MW of installed geothermal generating capacity and about 87 MW of biomass-fueled systems in the country.

6. These demonstration activities have established the technical performance of renewable energy systems in providing power. However, development of markets for power from renewable energy, and demonstration of cost-effective applications are only beginning in China.

Commercialization of Renewable Energy Systems in China

7. To realize its long-term social and development goals, GOC is recognizing the need to develop nonpolluting renewable energy sources on a major scale, over the long term, to help curb environmental damage. Concern is growing, within and outside China, about the environmental impact of massive and rapidly growing coal burning, and its consequences in terms of air pollution, acid rain and greenhouse gas emissions. Chronic pulmonary disease, linked to particulate pollution, is the number one cause of all adult deaths in China, at 26 percent of the total.

8. GOC's New and Renewable Energy Development Program aims to raise the efficiency of renewable energy, lower production costs, and enlarge its contribution to the energy system. From now to the year 2000, the plan calls for the creation of a modern industrial base and market infrastructure for production of mature technologies, such as wind generators and solar home systems. From 2001 to 2010, new technologies will be "popularized" and technology development in China will reach the level of industrialized nations.

9. However, according to Ministry of Electric Power (MOEP) targets, renewable energy (excluding small hydropower) will still account for only 1 percent of total power capacity by 2010. More ambitious development goals are needed, given the planned rapid

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[1] While small hydropower development is of great importance in China, it is not studied in depth in this report as it has been the subject of other World Bank, ESMAP and GOC studies. Also, large hydropower is considered a conventional technology that is outside the frame of new and renewable energy, as defined in the study.

development of coal-fired power plants. Without a strong push for renewable energy, coal use for power is predicted to increase by 3.5 times by 2010 and 5 times by 2020. Even with the use of pollution controls and "cleaner" coal burning technologies, the environmental damage from air pollution, acid rain and global warming would be serious. A stronger GOC program to develop a commercial renewable energy industry is urgently needed now, to help reduce the role of coal in China's energy balance in the long term.

10. China's efforts to develop renewable energy for power also need to be seen in an international context. One example is India, which also faces rapid growth in coal-fired power capacity, but has an ambitious plan to use renewable energy for power. In 1992, the Government of India shifted from a supply-based to a market-based approach to renewable energy development, using innovative financing models based on cost recovery and the private sector. As a result of the new approach, by late 1995 India had installed 560 MW of windfarms, 2 MW of PV, and 26 MW of biomass power, including 16 MW of cogeneration. India is on its way to installing 2,000 MW of renewable energy for power facilities by 2000 and 16,000 to 27,000 MW by 2015, through private-sector investment. By 2015, renewable energy is expected to account for 8 to 12 percent of total power capacity. India's forecast share of renewable energy in total generating capacity is especially notable because it started from near zero in 1992. This effort to support large-scale market development for renewable energy has already resulted in reduced costs through domestic manufacture of advanced technology and economies of scale.

11. Experience in other countries, including the United States and the United Kingdom, indicates that GOC needs to take a larger-scale and more market-based approach to renewable energy development. This means indirect government encouragement of investment rather than direct investment by government. It requires removing institutional barriers to investment, such as high perceived risk, lack of familiarity with proper power purchase agreements, high transaction costs, and poor access to credit. It also requires careful structuring of any financial incentives to support specific market development and cost reduction goals through increasing market size, developing local manufacture of advanced technologies, and developing market infrastructure. The objective must be development of technology packages that are cost-competitive with conventional technologies and can be sustained through market activity.

12. International experience with commercializing renewable energy indicates that a four-part approach is required: (a) identify technologies that are most promising in the near to medium term; (b) develop the market-based policies and institutional arrangements required to attract large-scale investment in the long term; (c) develop properly targeted financial incentives to accelerate market development of key technologies in the short term and to obtain the environmental benefits of renewable energy over the long term; and (d) "kick-start" key technologies through targeted assistance for investment and technical support, including research and development and demonstration.

Approach to Technology Evaluation

13. The study identified the most promising technologies in relation to four criteria: economic and financial viability; potential to contribute to power supply; environmental impact; and institutional and policy requirements for large-scale commercialization. For grid-connected systems, the economic value of power was estimated by conducting avoided cost analysis for the three networks on which projects were sited. Financial analysis was based on the prices that utilities are willing to pay for power from the projects studied. For off-grid systems, the focus was on organizational issues, such as product quality, marketing and distribution facilities, and service and maintenance support. Financial issues, such as access to credit and willingness to pay of potential users, were also examined.

14. Potential was first estimated as technical resource potential. Then, if possible, economically exploitable resource potential was estimated. Local and global environmental benefits were estimated based on avoided emissions from thermal plants.

15. The renewable energy applications selected for detailed analysis were: (a) grid-connected windfarms; (b) solar home systems; (c) bagasse cogeneration for surplus power production, as part of mill expansion; (d) grid-connected biogas power in large agricultural operations; and (e) geothermal power, assessing its potential to meet power demand in western China. Since potential viability can only be judged based on actual conditions, each technology was examined through a case study at a specific location. In addition to the applications listed above, the potential for four other technologies was examined: PV and wind hybrid systems, large biomass power, solar thermal power and small hydropower. Because small hydropower is already commercial and has been reviewed in detail elsewhere, the study looked only briefly at possible improvements to programs.

Conclusions of Technology Assessments

16. The study results indicate that windfarms, solar home systems and bagasse cogeneration projects have good potential to become commercially viable on a large scale. However, they need carefully targeted support from GOC in an initial phase of developing through commercial markets. Other technologies need further technical support before commercial development, but have substantial promise in the long term.

17. **Windfarm** projects have the largest potential to contribute to power supply and are fully economic at good sites, if local environmental benefits (health effects of offsets of emissions from thermal generation) are considered. GOC has given windfarm development high priority, setting a target of 1,000 MW installed by 2000. However, current financial returns are insufficient to attract large-scale utility or independent power producer (IPP) investment. To be sustained by investment in the long term, the following developments are required: (a) commissioning times would need to be reduced to about six months; (b) domestic manufacturing of advanced turbines must be established, which can reduce costs by some 20 percent; (c) standard power purchase contracts and

streamlined approval processes must be put in place; (d) wind resource data for prime sites need to be made available to developers; and (e) performance monitoring and analysis is needed to better understand the possible capacity benefits of windpower.

18. With a large-scale market development program, the recent experience in India indicates that these conditions can be expected to be met within five to ten years, after which further development will be fully financially viable through market channels. Given the quality and quantity of excellent windfarm sites that coincide with areas of load growth, GOC support to lay the foundation for a sustainable, commercially viable windpower industry should be given high priority.

19. *Investment* in commercial windfarm demonstration projects (100 to 200 MW), at high-potential sites such as Huitingxile, is a high priority, in order to (a) provide operating experience, reducing cost and performance uncertainties; (b) provide a market for gradual domestic manufacture of advanced turbines; and (c) establish an appropriate value for power from wind. As commercial windfarms take off, investment will be required in domestic manufacture of state-of-the-art, 500+ kW turbines. *Technical assistance* support required for windfarm development includes: (a) wind resource assessment at main potential sites; (b) monitoring of wind resources and performance at main existing sites; and (c) building the capacity of utility staff to support integration of windfarms with the grid, e.g., through analysis of loss-of-load probability (LOLP), estimation of capacity credits, and introduction of dispatch strategies.

20. **Solar home systems** (SHS) represent relatively small amounts of total power but address an essential need: the provision of electricity for basic needs of remote area households. A 12 MW SHS investment program could serve 500,000 homes in five northwestern provinces, equal to 25 percent of the unelectrified homes in these provinces. In the areas considered, SHS are least-cost electricity supply sources. They improve living conditions by providing new service levels well above those from kerosene/butter oil lamps and dry-cell batteries. A large-scale SHS program requires: (a) market development activities; and (b) improvement in module manufacturing and system assembly facilities, product certification and quality control, and sales and service support. Financial incentives and/or consumer credit are required to increase the market potential, in an initial phase. However, based on current international costs, PV system costs can be reduced by 10 percent within five years, reducing the need for financial incentives.

21. While the immediate environmental impact of displacing small quantities of fuels and batteries is not large, a SHS program on the scale described would triple the Chinese market for solar PV modules. The increased market would justify investment to improve existing manufacturing capacity and develop new capacity, which would reduce PV costs for the industry as a whole and increase the range of cost-competitive PV applications.

22. A GOC SHS development program would aim to rationalize the PV industry, increase market scale, lower costs and improve product quality, and develop commercial infrastructure. *Investment* priorities are (a) an SHS market development program, to provide electricity to 500,000 households in five northwestern provinces (12 MW);

(b) installation of centralized PV stations and PV/wind hybrid stations in remote county towns, where cost-effective; and (c) strategic expansion of silicon manufacturing, module and balance of systems manufacturing, and system assembly operations.

23. *Technical assistance* priorities are to: (a) develop a PV industry sector strategy to increase efficiency and lower costs; (b) establish product specifications and a national quality certification agency to test and qualify products; (c) provide product and business development assistance to PV system suppliers; (d) training and support for sales and service networks; and (e) market studies and consumer education programs.

24. **Bagasse cogeneration systems** to produce surplus power have more limited potential than some other renewable energy sources, but offer immediately attractive investment opportunities, on both an economic and financial basis, with an EIRR estimated at 33 percent and FIRR at 20 percent. While bagasse cogeneration for *in-mill* energy needs is currently practiced, generation of surplus power for sale to the grid is not. The potential for surplus power production, to 2000, is 350 to 450 MW in Guangxi alone, and 700 to 900 MW in the primary sugar-producing regions. As the sugar industry continues to grow, the potential will expand beyond 2000. To obtain this potential, the sugar industry needs access to long-term debt financing on commercial terms, and technical assistance to develop mill-specific design and operating plans.

25. The study indicates that *investment* in bagasse cogeneration for surplus power production is a high priority, including: (a) installing cost-effective generating capacity as part of a mill expansion program in Guangxi, to deliver surplus power to the grid, estimated at 350 to 450 MW; and (b) similar cogeneration investments in other provinces. *Technical assistance* priorities for GOC support include the following: (a) feasibility and detailed design studies for cogeneration in sugar mills; (b) immediate demonstration of a surplus power system in one plant; and (c) development of power purchase agreements and investigation of grid integration issues.

26. **Other Technologies.** Biogas power projects are generally economic but have low financial viability. In addition, the total economic potential nationwide was found to be small (100 MW) in comparison with the other grid-connected options. For geothermal power, work is still needed to define the resources available and to estimate the benefits and costs of a proposed 10 MW installation in Tengchong County, west Yunnan, as well as to gauge national potential.

27. *Investments* in other technologies are considered to be of lower priority, since their potential commercial markets are more limited. Other recommended investments are: (a) subject to feasibility work, geothermal power facilities in Tengchong County, Yunnan, and in other locations; (b) biogas power plants at large piggeries (>50,000) and other large livestock operations; and (c) small wind generators, and wind/PV hybrids, as part of off-grid electrification programs.

28. Study results indicate that GOC needs to initiate or continue *technical assistance* activities, including research, development and demonstration of the following technologies, in addition to windpower, solar PVs and bagasse cogeneration:

- Small hydropower—improve designs, efficiency of equipment, economic evaluation of projects, pricing of power.

- Biomass for power—assess the feasibility of biomass for power production from other captive wastes and from biomass plantations in areas such as Yunnan; and further review technical and economic issues, and environmental externalities associated with large-scale biogas generation.

- Geothermal energy—investigate the potential of geothermal energy in Tengchong County, through geoscientific investigation, well drilling and prefeasibility work; and reassessment of resource data for the rest of the country.

- Solar thermal power—study economic and financial feasibility of parabolic trough thermal/coal hybrid power plants in selected sites; and maintain a watching brief on parabolic dish/Stirling engine system commercialization.

- Small wind and wind/PV hybrid systems—include small wind generators and wind/PV hybrids in off-grid electrification programs to serve unelectrified households.

Institutional and Policy Issues

29. The key issue is how to move power-related renewable energy applications from a demonstration to commercial stage. This will require large-scale investment from a variety of sources, both foreign and domestic. Experience from other countries provides lessons in the types of policies, incentives and other support that have been used and their results, positive and negative. GOC urgently needs to study, review and act on the following issues, in collaboration with key provincial governments.

30. GOC needs to strongly support renewable energy development, by increasing awareness of the technologies among government and energy company officials, and by better integrating renewable energy development into the nation's overall energy development program. Cooperation among the three commissions charged with responsibility for renewable energy development needs to be strengthened, as well as the capacity of each commission to play its role, especially SETC in leading commercialization efforts.

31. GOC should create a policy/regulatory framework that facilitates investment in renewable energy for power, in the long term. The following barriers need to be addressed:

- the lack of standard power purchase agreements and tariffs for small-scale power producers;
- the lengthy and complex approval processes for even small- to medium-size power facilities;
- limited access to credit through commercial banks, investment banks and the bond market, because of their undeveloped state in China, lack of experience with renewable energy and consequent perception of high technology risk; and
- lack of standards, certification procedures or other quality assurance measures for renewable energy technologies.

32. GOC also should consider putting in place modest, time-bound financial incentives, where they are deemed necessary, as part of a deliberate market development and cost reduction program. While some renewable energy technologies are financially viable today, such as bagasse cogeneration for surplus power, others may require targeted financial incentives during the initial phase of market development, to remove barriers and to reduce high implementation costs due to low market volumes. Incentives in place in China have not been effective in generating the large scale of activity required to reduce costs.

33. Where an incentive is considered, GOC needs to: (a) set the level of the financial incentives based on the difference between the current cost of power and its expected long-run economic value; (b) set a time boundary on the incentive and monitor cost reductions over time; and (c) ensure that the incentive mechanism does not create distortions in the market.

34. Especially in the case of solar PV, where scale is a critical factor, an overall development plan for the sector is needed, to ensure economic efficiency in light of potential domestic and export markets.

35. GOC also needs to study the damage costs from conventional power generation, in order to assign a value to the environmental benefits from renewable energy and work toward incorporating these benefits in economic and financial assessment of alternatives.

Conclusions and Recommendations

36. GOC needs to take a larger-scale and more market-based approach to renewable energy development in China, including: (a) identifying the most promising technologies; (b) setting an appropriate policy and institutional framework to encourage development through commercial markets in the long term; (c) reviewing and restructuring financial incentives as part of a program to stimulate market demand and investment, in the medium term; and (d) providing investment, technical and other assistance to accelerate market development of the most promising technologies in the short term.

37. This joint study has begun the process of identifying promising technologies. GOC needs now to give urgent priority to setting the policy framework; putting in place appropriate financial incentives, where necessary; and preparing and implementing investment and technical assistance projects. Priorities that emerge from the study for investment and technical assistance are summarized in Table 1.

38. Expanded support from multilateral and bilateral agencies will be important to implement many of the priority investment and technical assistance activities outlined below. International assistance is especially important in the following areas: (a) assistance in reviewing options for promotion policies and financial incentives to encourage investment in renewable energy facilities; (b) demonstration and transfer of advanced technology to China, to lower costs and improve technology performance; (c) assistance in developing institutional arrangements, e.g., in developing power purchase agreements for windfarms and biomass plants, and developing standards and certification procedures for equipment; and (d) provision of additional long-term capital from international public and private sources. Resources from the Global Environment Facility (GEF) can be used to promote and accelerate priority policies, investment and technical assistance projects for renewable energy development in China.

TABLE 1: PRIORITIES FOR INVESTMENT AND TECHNICAL ASSISTANCE

Areas for Development	Investments	Technical and Other Assistance	Expected Results
Policy	n.a.	• Strengthen three commissions and improve coordination • Make Renewable Energy Development Program larger-scale, more market-based • Develop policies to encourage small power production from renewable energy • Review and restructure financial incentives • Develop industrial strategy for key technologies • Analyze and value environmental benefits from renewable energy for power	Develop institutional and policy framework to encourage large-scale public and private investment
Windfarms	• Commercial-scale windfarms at Huitingxile or similar sites (~1,000 MW) • Large, 500+kW wind turbine manufacture	• Wind resource and performance monitoring of existing windfarm sites and grid interconnection • Wind resource assessment at potential and new sites • Capacity building of power utility staff	Build portfolio of windfarm projects, reduce uncertainty, reduce costs, demonstrate commercial arrangements, reach financial viability.
Solar Home Systems	• 500,000 households off-grid electrification program • Expand silicon manufacture • Expand module and balance-of-system components manufacture • Expand systems assembly operations	• PV industry sector development strategy • SHS product development, business development and planning • Product certification and quality control • Training and support for sales and service network • Consumer education	Rationalize PV industry, increase market scale, lower costs and improve quality, develop commercial infrastructure, increase productivity of PV module industry
Bagasse Cogeneration	• 350 MW, 39 mill expansion project in Guangxi (funding required urgently to coincide with increased sugar processing capacity investments) • Cogeneration in other provinces	• Conduct feasibility and detailed design studies for sugar mills in Southern provinces • Prepare guidelines and designs for advanced cogeneration investments involving high temperature/pressure equipment • Develop a demonstration project • Develop PPA and investigate grid integration issues	Produce power on commercial basis and serve as model for standard procedures in future mills
Small Hydro	• Further investment, especially to improve efficiency and regulated capacity	• Automation, efficiency improvement, quality control, design improvement, economic evaluation	Increased effectiveness of existing program.
Geothermal Power	• Conduct feasibility study of 10 MW facility in Tengchong County, Yunnan • Subject to feasibility, production well and power plants at other sites	• Geoscientific investigations, exploratory well testing Rehai geothermal field and if warranted, feasibility study for development of Rehai field • Reassessment of geothermal potential, including both resource data and economic viability in western Yunnan and Tibet	Investment at Rehai and other sites depending on results of feasibility studies and resource assessments
Biogas for Power	• Biogas and power generation plants at large piggeries (>50,000 pigs) and other livestock operations	• Study of areas for technical improvements, environmental externalities and any incentive measures justified • Exchange of information on improving process efficiency, engine performance, develop low-cost materials	Reduce effluents from large agricultural operations
Solar thermal electric, wind and PV hybrids	• Include wind and PV hybrids in off-grid electrification program	• Develop/introduce advanced design techniques • Assist product development of hybrids • Examine potential for advanced wind-PV, PV diesel and other hybrids • Evaluate feasibility of parabolic trough technologies in regions other than Tibet with higher demand and availability of back-up fuel • Assess feasibility of coal-solar thermal parabolic trough designs • Pilot projects involving solar thermal dish Stirling and other advanced power generation technologies	Add to portfolio of off-grid and grid-connected technologies

1. INTRODUCTION

1.1 The Government of China (GOC) is giving increasing attention to renewable energy development for power, to provide least-cost electricity to remote areas, and, in the longer term, to diversify energy sources and to curb growth in pollution from coal plants. In 1995, the State Planning Commission (SPC), the State Science and Technology Commission (SSTC), and the State Economic and Trade Commission (SETC) jointly formulated a Program of New and Renewable Energy Development, 1996-2010, and an implementation plan for the Ninth Five-Year Plan (1996-2000), based on the Program. The Electricity Law, passed in December 1995, also supports the development of renewable energy. The new Law advocates the use of rural hydropower resources, solar, wind, geothermal, biomass and other energy for rural electrification and power generation.

1.2 Given the commitment by the Chinese Government to the development of renewable energy, the World Bank and GOC have carried out this study, with the assistance of a team of Chinese and international experts. The objective is to identify priorities for power-related renewable energy development in China. GOC has completed a complementary study of direct thermal applications of renewable energy, using a similar methodology, with assistance from the Global Environment Facility (GEF). Together, the two studies provide a comprehensive assessment of renewable energy development priorities in China.

1.3 This study includes: (a) assessments of the technical, economic and financial viability of power-related renewable energy technologies, compared with conventional technologies; (b) a review of institutional and policy issues affecting development of these technologies; and (c) an outline of priorities for investment and technical assistance support.

1.4 The main body of the study is composed of the following Chapters. Chapter 2 discusses the status of renewable energy development in China, for power generation, and analyzes GOC's Renewable Energy Development Strategy in the light of international experience. Chapter 3 summarizes the technology assessments, with details given in Annexes 3 and 4. Chapter 4 outlines the main institutional and policy issues affecting development of renewable energy for power in China. Chapter 5 presents the study conclusions and recommendations.

2. RENEWABLE ENERGY DEVELOPMENT STRATEGY OF THE GOVERNMENT OF CHINA

A. Environmental and Social Impetus for Development of Renewable Energy for Power

2.1 China is on a path of strong and steady economic growth, fueled by expansion of the domestic market and exports. Economic growth averaged 11 percent from 1978 to 1993, and is expected to continue to 2020 at an average of 8 to 9.5 percent annually. The future of the economy is promising, but in order to sustain the expected growth rates China faces a number of challenges. Two of the most important are: (a) reducing the adverse environmental impacts associated with rapid economic growth in a coal-based economy; and (b) improving social equity by increasing the services available to the 80 to 100 million people living in highlands, deserts, steeply sloping and reservoir areas, mainly in the northwest and north-central parts of China.

2.2 Environmental problems in China are serious and growing, especially those caused by burning coal for energy and power. Urban air pollution in most cities exceeds international standards by a factor of three to five times. Air pollution contributes to chronic respiratory disease, cancer and premature illness and death. Chronic pulmonary disease, linked to particulate pollution, accounts for 26 percent of all adult deaths in China. This is the largest single cause of adult deaths in China, at five times the US rates.[1] Acid rain is increasingly serious, especially in southern China, damaging forests, crops and animal life in water bodies.

2.3 The power sector accounted for about 25 percent of coal use in 1990, expected to increase to 40 percent by 2020.[2] Coal use for power is expected to increase from 251 to 1,300 million tons between 1990 and 2020. Concern is growing, within and outside China, about the environmental impact of such massive coal burning, and its consequences in terms of air pollution, acid rain and greenhouse gas emissions. To realize its long-term social and development goals, GOC urgently needs to develop nonpolluting renewable energy sources that can reduce the growth in coal use and help to curb environmental damage.

2.4 The other set of challenges faced by GOC is related to poverty and the need to balance the benefits from economic growth among the different parts of the country.

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1 World Bank, 1992, *China Environmental Strategy*, p. x.

2 See NEPA/UNDP/World Bank, *China: Issues and Options in Greenhouse Gas Emissions Control*, 1994, p. 22.

GOC is committed to providing better social services in the poorer, more remote regions of the country. Off-grid renewable energy for power can improve the quality of life in these areas by offering a whole new level of services to households, above the kerosene/ butter lamps and dry-cell batteries now in use. Services include electric light, use of cassette players and television.

2.5 The Electricity Law of 1995 supports the use of renewable energy for rural electrification and power generation. This law adopts preferential policies for rural electrification and offers special support to areas inhabited by minority nationalities, frontier and remote areas, and poverty-stricken areas (see Articles 47 and 48). This is related to GOC's ambitious "8-7" plan, which aims to improve social equity by raising agricultural output and improving services to 80 to 100 million poor people living in remote areas.

B. Resource Base and Status of Power-Related Renewable Energy Development In China

2.6 Renewable energy for power generation has large potential in China. China has a rich resource base, found mainly in areas without conventional energy resources. However, with the notable exceptions of small hydropower and small wind generators, development to date has been on a government-sponsored research and demonstration scale. Small hydro is a fully-commercialized technology, with an installed capacity of 15 GW in 1993, about 8 percent of the total national installed generation capacity.[3] Government promotion programs, led by the Ministry of Water Resources, continue the development of the remaining exploitable small hydro potential, estimated at 56 GW. The majority of the small hydropower (SHP) potential lies in the south/central provinces where forestry resources have traditionally been used for energy, and where difficult terrain isolates many communities.

2.7 The exploitable wind resources are very large, estimated at 250 GW, mainly distributed in two large wind belts: the Coastal wind belt; and the Northern wind belt from Xinjiang via Gansu to the plateau of Inner Mongolia. At end-1994, China had 14 grid-connected windfarm sites with a total installed capacity of 30 MW, and over 140,000 small wind turbines (50 to 5,000 W) with a combined off-grid capacity of 17 MW. There is a domestic manufacturing base for small-scale wind turbines, although there is no capacity for large turbines of 200 kW and greater. Solar resources are distributed widely, but the plateau areas of northern and western China have excellent solar insolation. There were about 3 MW of solar photovoltaics (PV) installed in China at end-1994, of which about a third was in dispersed household systems.

2.8 While there are only 30 MW of installed geothermal generating capacity in China, estimates of theoretical resource potential exceed 6.7 GW. However, many of the resources are not located near existing grids and cannot be economically exploited. The

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[3] Small hydropower is defined as <25 MW in China.

greatest potential for geothermal power facilities lies in the high-temperature resource zones in Tibet, Yunnan, and Sichuan Provinces, although low-medium temperature resources for power generation using binary-cycle technologies exist throughout China.

TABLE 2.1: GEOGRAPHICAL AREAS WITH HIGHEST RESOURCE POTENTIAL

Resource	Criteria for Selection of Areas	Areas with Significant Potential
Small Hydro	Provinces with Remaining Potential Greater than 1,000 MW	Tibet, Yunnan, Sichuan, Xinjiang, Hunan, Hubei, Guangdong, Fujian, Zhejiang, Guizhou, Jiangxi, Qinghai, Shanxi
Wind	W_{ave}>200W/m^2, V>3m/s for > 5,000 hrs	Southeastern coast and 6300 islands, northern Inner Mongolia and Gansu, eastern Heilongjiang and Jilin, Xinjiang
Solar	Class I and II >3,000 hrs/yr >5,000 MJ/m^2/yr	Ningxia, Mid-North Gansu, South Xinjiang, Qinghai, Southeast and West Tibet, North Hebei, North Shanxi, Inner Mongolia
Geothermal	High Temperature >150°C	Southern Tibet, Western Yunnan and Sichuan, Taiwan, Fujian, Guangdong
Biomass	Bagasse, Forest Residues	Yunnan, Guangdong, Guangxi

2.9 China has limited experience with biomass power systems (total generating capacity of 87 MW at end-1994). Although biomass is heavily utilized in China in small-scale traditional applications and in biogas plants, opportunities for large-scale power generation have yet to be captured. The sugar industry in south-coastal regions could have significant potential for surplus power generation.

2.10 In summary, development of China's rich resource base of renewable energy for power has been minimal, and mainly on a research and demonstration level. Only small hydro, and, to a lesser extent, small wind generators have been developed commercially. Compared to most countries, however, China's achievements in overall renewable energy development have been notable. Aside from small hydro, it is widely recognized as a world leader in its programs on nonpower technologies, including efficient fuelwood stoves, solar water heaters, and biogas digesters. In the development of large-scale power generation from sources other than small hydro, the country lags behind India. In September 1995, India had a total of 560 MW of grid-connected windpower, 2 MW of installed solar PV, and 26 MW of biomass for power, including 16 MW of bagasse cogeneration.

C. GOC'S NEW AND RENEWABLE ENERGY DEVELOPMENT PROGRAM, 1996-2010

2.11 However, this situation is beginning to change as GOC aims to move renewable energy development forward from demonstration to commercialization. The "White Paper on China's Population, Environment, and Development in the Twenty-First Century" represents a strategic plan for sustainable development, including renewable energy. This plan was approved by the State Council on March 25, 1994 and serves as a guide for medium- and long-term economic and social development of renewable energy technologies, leading to the preparation of the New and Renewable Energy Development Program. Three major commissions, SPC, SETC and SSTC, prepared the joint New and Renewable Energy Development Program, 1996-2010. While the program builds upon previous efforts,[4] it marks a new level of commitment by GOC.

2.12 Its objectives are to raise the conversion efficiency of renewable energy, lower the production costs, and enlarge the contribution of renewables to the energy system. This will be accomplished in two stages. In the first stage, from now to the year 2000, the emphasis will be on creating the modern industrial base and market infrastructure for production of mature technologies such as wind generators and solar PV systems for homes and communities. At the same time, research and demonstration projects will be done to bring other technologies to maturity. In the second stage, from 2001 to 2010, new technologies will be "popularized" and technology development in China will reach the level of industrialized nations. The main tasks set for each technology are the following:

- for small hydro, to continue development so that installed capacity increases as shown in Table 2.2, to 20 and 28 GW by 2000 and 2010.

- for wind, the emphasis is on: (a) marketing of small-scale wind generators; (b) improving the performance of wind turbines; (c) developing local production capacity for wind turbines with capacity above 200 kW; (d) developing wind power control and management systems; (e) strengthening the capacity for wind measurement, planning, site selection, and design; and (f) construction of 1,000 MW of large-scale windfarms by 2000 and 3,000 MW by 2010.

- for solar PV power, efficiency will be improved and system costs reduced through development of low-cost solar cells and associated equipment. The construction of PV power stations in nine Tibetan counties without power should be completed by 2000. Small PV systems should be promoted vigorously supplying the needs of the 28 counties, 10,000 townships and 1,000 islands without access to electricity. Distributed and centralized MW-scale PV power stations connected to grids should be demonstrated.

- for geothermal energy, the aim is to actively exploit the resources in regions with high temperature resources, while solving problems of geothermal corrosion and water recharge. The use of heat pumps will be encouraged.

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[4] Including renewable energy programs in the National Science and Technology Development Program in the Sixth Five-Year Plan (1981-85), the Seventh Five-Year Plan, and Eighth Five-Year Plan.

- for biomass, plans call for capacity of power stations using rice husks, wood scraps, and bagasse to be 50 MW or more by the year 2000, and 300 MW by 2010. Biogas for power plants is not included in this estimate.

2.13 Plans for power-related renewable energy projects are part of GOC's aim of providing power service to all counties and increasing the coverage of electricity supply to 95 percent of the population.[5] The focus in the short term is on service to remote areas and islands, and development of nearly commercial applications like grid-connected windpower. Plans of the Ministry of Electric Power (MOEP) and the Ministry of Water Resources (MOWR) give concrete targets to the more general development framework described above (see Table 2.2).

TABLE 2.2: CURRENT AND FUTURE INSTALLED CAPACITY OF RENEWABLE ENERGY FOR POWER, FROM MOEP PLANS (MW)

Technology	Actual 1993	Planned 2000	2010	2020
Small Hydro	15,055	19,850	27,880	39,158/a
Wind	30	1,000	3,170	8,500
Solar PV	3	35	200 (PV and thermal)	500 (PV and thermal)
Geothermal	30	106	200	330
Solar Thermal	-	35	included in PV	included in PV
Biomass	87	n.a.	n.a.	n.a.
Ocean	0	0	200	400
Total Renewables	**15,211**	**20,726**	**31,650**	**48,888**

/a Estimated.

Source: Renewable Energy Development Program and MOEP Plans.

2.14 Renewable energy development is being given priority in several provinces. In Qinghai, Tibet and Inner Mongolia, rural electrification plans of the Provincial Power Bureaus/Corporations include support and targets for rural electrification using SHS, windpower, centralized PV and diesel/wind and/or PV hybrids. Inner Mongolia and Xinjiang have established targets of 200 to 400 MW and 100 MW of grid-connected windfarms by 2000, respectively.

D. ANALYSIS OF GOC'S RENEWABLE ENERGY DEVELOPMENT PROGRAM—LESSONS FROM OTHER COUNTRIES

2.15 The MOEP plans, as laid out in Table 2.2 will achieve only a modest increase in the role of renewable energy in power generation, in relation to the rapid planned expansion in coal-fired generation capacity, which is expected to increase 3.5 times by

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5 See Zheng Qiren, MOEP, "To Develop Renewable Energy Actively and To Speed up Utilization of New Energy Resources for Electricity Generation Technology," in *Solar Energy in China*, Proceedings of the High Level Expert Meeting for China, Beijing, China, 1995.

2010 and 5 times by 2020. The share of renewable energy, other than small hydro, would increase from insignificance in 1994 to 1.3 percent in 2020. While the growth in renewable energy generation capacity is significant, the starting base is so low that it will not contribute substantially to the power balance of China during the planned period without even more aggressive expansion. China's small hydropower program is not expected to keep pace with growth in coal-fired power generation, with its share expected to decrease from 7.5 percent in 1994 to 5 percent in 2020. Faced with serious environmental problems from its massive and growing burning of coal, GOC needs to adopt a bolder approach to development of renewable energy power than is suggested by current plans, in order to make an impact in the long term.

TABLE 2.3: ESTIMATED SHARE OF RENEWABLE ENERGY IN POWER GENERATING CAPACITY IN CHINA, 1994-2020

	1994	2000	2010	2020
Thermal Capacity (GW)	-	188	384	595
Hydro and Other (GW)	-	86	127	169
Total (GW)	199	274	511	764
Small Hydro (GW)	15	19.9	27.9	39.2
Share Small Hydro (%)	7.5	7.3	5.5	5.1
Other Renewable Energy (GW)	0.1	0.9	4.1	9.8
Share of Other Renewable Energy (%)	0.0	0.3	0.8	1.3

Source: *China: Issues and Options in Greenhouse Gas Emissions Control*, and Table 2.2

2.16 The GOC approach described above, of developing manufacturing and marketing infrastructure in the first phase and "popularizing technologies" with state investment in a second phase, is rooted in central planning. This approach was used for small hydro, where MOWR supported small hydro development through a combination of developing technology packages, staffing local offices to provide support for small hydro promotion and design, and providing investment funds to participating communities. Governments no longer have the resources to support development in this way.

2.17 GOC needs to provide strong government support for renewable energy development through the market by: first, encouraging the development of markets for renewable energy technologies; and then encouraging local production capacity and infrastructure to develop, following actual market demand, as appropriate. This is the approach being used successfully by India and a number of other countries. Financial incentives and government-assisted investment programs have been used to "kick-start" markets for renewable energy power in most of the leading countries, including the United States, the United Kingdom, Germany and the Netherlands.

2.18 The issue for GOC is how to mobilize resources to develop the most commercially viable technologies, rapidly and on a large scale. Experience in other countries suggests that GOC assist the development of commercial markets for renewable energy by:

(a) identifying technologies that are the most promising in the near to medium term; (b) developing policy and institutional arrangements to encourage long-term investment in renewable energy for power facilities and manufacturing capacity; (c) developing financial incentives to accelerate market development for key technologies and encourage investment in the medium term; and (d) "kick starting" development of key technologies through investment and technical assistance in the short term. The elements of this strategy are analyzed in the following chapters, beginning with the assessment of technologies.

3. TECHNOLOGY ASSESSMENTS

A. SELECTION OF TECHNOLOGIES

3.1 Detailed assessments were carried out by the study team, to determine the economic viability of power-related renewable energy technologies in China; their potential contribution to power requirements; and actions required to accelerate their development. Technologies were selected for analysis based on the following criteria: (a) potential for large-scale application in regions of China with growing power demand; (b) short- to medium-term technical and economic viability, as demonstrated in China or elsewhere; and (c) the interest of GOC, as expressed in the Renewable Energy Development Program, or in provincial plans for power facilities.

3.2 Since viability can only be judged based on actual conditions, sites were selected for analysis based on: the resources available, local demand for power, and potential for replication to other sites. After site-specific analysis was completed, the potential application of the technology on a broader scale was assessed. The technologies and sites selected for detailed analysis were:

(a) Grid-connected **windfarms** focusing on a 100 MW installation at Huitingxile in Inner Mongolia and an 11.2 MW installation on Nan'ao Island. The former evaluates large windfarms feeding extensive power networks, while the latter assesses smaller windfarms feeding island grids with multimegawatt capacity.

(b) **Solar home systems**, examining a 50,000-home project in unelectrified counties in Qinghai province. Qinghai serves as a model for other northwestern provinces with large unelectrified populations.

(c) **Bagasse cogeneration**, looking at a mill expansion case (3,000 to 5,000 tons of cane per day) in Guangxi province, where the milling season coincides with hydropower supply shortage in the dry season.

(d) Grid-connected **biogas power**, examining a 15,000 pig breeder farm project outside Beijing, where there is a need to treat the plant waste and gas production far exceeds cooking and other thermal needs of the farm and facility.

(e) **Geothermal power**, focused on the potential for meeting power demand in western Yunnan and the Tibet region. A number of counties with geothermal resources have supply shortages on isolated grids during the dry season.

3.3 In addition to the detailed assessments, analysis was done to answer questions about other renewable applications. To assess the potential for **large biomass power facilities**, the study assessed the scale, location and utilization of biomass resources, to determine if large biomass-fueled plants similar to the one being developed in Brazil may be attractive in China. For **small hydro**, the objective was to determine what improvements are needed in existing programs. With regard to **solar thermal power,** the potential for parabolic trough and other technologies was discussed. Finally, the potential for household **PV/wind hybrid systems** and community **PV/diesel hybrids** was examined, because of the cost advantages of complementarity in areas such as Inner Mongolia and Tibet.

B. EVALUATION FRAMEWORK AND METHODOLOGY

3.4 The following framework was used to analyze and evaluate each of the main technologies: (a) site-specific economic and financial viability of a proposed project; (b) potential of the technology in China; (c) technical and policy requirements for development; and (d) environmental impact. Conventional economic and financial benefit/cost analysis was done using standard World Bank project appraisal techniques, excluding environmental externalities. The criterion used to judge economic and financial viability was a cutoff of 12 percent for economic internal rate of return (EIRR) and a judgment of about 15 to 20 percent for the financial internal rate of return (FIRR), equivalent to returns on other investments in China, both in real terms.[6] The potential for the technology was estimated, first, based on the national theoretical resource potential. If possible, an estimate was made of the exploitable potential, considering the extent to which the resources are located near growing power demand and can be economically exploited. Technical and policy requirements for large-scale commercial exploitation include such issues as the need for resource assessment, power purchase agreements, credit for consumer purchase of off-grid systems, etc. After the technology assessments, this chapter contains a section analyzing the environmental benefits of the main technologies. The results of the evaluations are summarized in Chapter 5.

3.5 **Grid-Connected Renewable Energy for Power Technologies**. Economic and financial capital and operating costs were estimated. The economic analysis included estimation of avoided cost for power generation from conventional alternatives, to establish the value of power from renewables.[7] Avoided costs were estimated for the three grids on which facilities were sited—the JJT Main Power Grid (Beijing-Tianjin-Tangshan, see Annex 1), the Guangdong Grid and the Guangxi Grid. The avoided cost estimate includes avoided capacity, energy and network costs, by peak/nonpeak period

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6 The EIRR is calculated from the national viewpoint, excluding financing charges, duties and taxes. The FIRR is calculated in constant yuan, assuming 100 percent equity financing and before income tax. It includes customs duties, the VAT, and the VAAT, although not local taxes because of incomplete data.

7 In fast-growing systems such as these, avoided cost means the cost associated with the deferred future increment of energy or capacity rather than the avoided use of existing capacity.

and by wet/dry season. Long-term load forecasts and investment plans were used in estimating avoided cost. Power production from the renewable energy facility was estimated for the corresponding periods and a weighted-average avoided cost derived for power from the facility.

3.6 The financial analysis includes customs, duties, value-added tax (VAT) and additional value-added tax (VAAT). Customs duties on renewable equipment were estimated at 12 percent long-term in the analysis, based on information from the SETC expert team. The VAT is 17 percent, while the VAAT is calculated as 8 percent of the VAT. Because renewable energy facilities are capital-intensive, these taxes add a heavy burden to their costs in initial years that cannot be carried forward and offset against profits. The power purchase price used in the financial analysis is the price that utilities are willing to pay for power from the specific project. The FIRR was first calculated from a national perspective, in real yuan before financing and income taxes. A second financial rate of return on equity (FIRREQ) was calculated, after income tax, in current yuan, based on assumptions about financing. The FIRREQ is calculated after income tax, in current yuan, assuming that 70 percent of the investment was financed with a 10-year loan at 15 percent interest. While financing arrangements may differ, the FIRREQ is an indicator of the attractiveness of equity investment. It overstates real returns, as it does not include local taxes and charges.

3.7 **Off-Grid Technologies**. For off-grid technologies, the assessment followed a similar approach, but examined organizational and financial issues in greater detail. Off-grid, household-scale technologies are large-cost consumer items. Prerequisites for success of such technologies are adequate manufacturing and assembly infrastructure, good-quality products, marketing and distribution facilities, and service and maintenance support. Willingness and ability to pay of potential users are also important issues. Access to credit is important for affordability of larger systems.

C. Grid-Connected Windfarms

Background

3.8 Windfarms are given high priority by GOC for immediate development. China has world-class wind resources, with a total technical potential estimated at 250 GW.[8] With bilateral assistance, 163 imported wind turbines (total capacity of 30.1 MW) were installed at 14 sites by the end of 1994. Installation of 550 to 600 kW machines is underway at a few sites, giving Chinese experts technical and operational experience with advanced, imported units. In addition, Chinese wind experts have conducted wind resource measurement programs at main sites.

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8 This compares to an estimated *exploitable* potential of 56 GW for small hydro. Exploitable potential of wind has not yet been estimated, but is probably similar to small hydro.

3.9 GOC has a stated goal of installing 1,000 MW of grid-connected windfarms by 2000, an ambitious goal given that total installed capacity worldwide was only 5,000 MW at the end of 1995. Inner Mongolia, Xinjiang and Guangdong also support grid-connected windfarm development.

Development Potential

3.10 While definition of the prime sites for windfarms is at an early stage, MOEP has investigated the main known sites and estimated the near-term potential at 1,000 MW (see Table 3.1). The longer-term potential is many times this, for these sites alone. All of the sites have attractive wind speeds, and are located on grids with growing demand for power. The most attractive site, in terms of wind speed, site potential and location, is Huitingxile, Inner Mongolia. Inner Mongolian sites have the largest potential in the medium term, because they are interconnected with the large JJT Main Power Grid. The provincial government is supportive of windfarm development. If 1,000 MW of windpower were developed by 2010, this would amount to about 2 percent of the total capacity on the JJT portion of the North China grid.

TABLE 3.1: CHARACTERISTICS OF MAIN KNOWN WINDFARM SITES

Potential Windfarm Site, Province	Average Annual Wind Speed at 10 m (m/s)	Estimated Capacity Factor (Percent)	Available Land Area (km^2)	Maximum Potential of Windfarms (MW)	Year 2000 MOEP Windfarm Plan (MW)	Yr 2000 Grid Capacity (MW)
Huitingxile, Inner Mongolia	7.2	39	100	1,000	360	21,000
Zhurihe, Inner Mongolia	6.4	27	n.a.	-	52	21,000
Boyonghu, Jiangxi	7.6	46	45	450	47	6,800
Nan'ao, Guangdong	8.5	34	20	200	100	23,000
Huilai, Guangdong	n.a.	-	n.a.	-	30	23,000
Dabacheng, Xinjiang	6.2	25	100	1,000	100	5,000
Zhangbei, Hebei	6.8	33	20	200	52	1,300
Hedingshan, Zhejiang	n.a.	-	7.5	750	20	
Kuocangshan, Zhejiang	n.a.	-	n.a.	-	40	
Donggang, Liaoning	6.7	31	12	120	34	
Tongyu, Jilin	6.0	23	n.a.	-	56	
Changdao, Shandong	6.0	23	n.a.	-	12	
Laizhou, Shandong	5.9	21	n.a.	-	10	
Dongchudao, Shandong	6.6	30	n.a.	-	10	
Dongfang, Hainan	6.4	27	n.a.	-	50	3,500
Total				**~3,700**	**973**	

Notes: About 10 MW can be installed per square kilometer (km^2) of land. Typically, wind generating capacity should be about 15 percent or less of grid capacity, depending on local grid conditions. Capacity factor is estimated using 40m hub heights, and shear index of 0.144, except at Nan'ao which has a shear index of 0.

For purpose of comparison, the *best* wind farm site in India (Muppandal in Tamil Nadu) has an average annual wind speed of 6.08 m/s at 10m and 8.15 at 40m (Huitingxile wind speed at 40m is 8.8 m/s).

Source: Data from the SETC Expert Team, January 1996. Further monitoring, data verification, and refinement of estimates is required.

3.11 Although the Dabacheng site in Xinjiang has good wind speeds and potential, Xinjiang's power network is made up of isolated grids. The capacity of the entire network will be about 5,000 MW by 2000. A 600 MW pumped hydro facility is planned on the largest single grid, around Urumqi. This could be an advantage, since it indicates that windpower could be "stored" and given a capacity credit. However, development of the site will be limited by penetration limits on small, local grids (see note in Table 3.1). Windpower development on islands where wind resources are good and alternatives expensive could be attractive. Coastal provinces like Guangdong and Zhejiang are also likely areas for windfarm development.

Project Analysis

3.12 Because of the large potential of windfarms, two projects were assessed: a 100 MW windfarm at Huitingxile, Inner Mongolia, representing large windfarms feeding extensive grids; and, an 11.2 MW windfarm on Nan'ao Island, Guangdong, representing windfarms that contribute a significant portion of local requirements on smaller island grids.

Project Descriptions

3.13 **Huitingxile**. This site has the potential for large-scale development in the medium term. It is on a transmission line of the JJT Main Power Grid, which stretches from Inner Mongolia to the cities of Beijing-Tianjin-Tangshan. In 1995, the JJT grid had a capacity of 14,736 MW.[9] Annual load growth is projected at 9 percent to 2000. Since the Inner Mongolia grid is being developed to supply Beijing, large investments in coal-fired power plants, pumped storage and transmission are planned.

3.14 The windfarm site has an average wind speed of 8.8 meters per second (m/s) at 40 meter height, superior to most sites being developed in the United States and Europe. A 110 kilovolt (kV) line passes through the windfarm site, which is located on a highway about 120 kilometers (km) from Hohut. Another 110 kV line is under construction. There is no land constraint at the site, which is on a plateau that could be developed for 1,000 MW. However, the impact of a large windfarm on the local grid stability needs to be investigated and taken into account in planning.

3.15 The analysis assumed development of 100 MW of capacity at the site using 550 kW imported turbines, with increments of 20 MW added over a two-year period. The capacity factor was estimated at 39 percent, with annual production of 270 gigawatt-hours (GWh) per year, of which over 70 percent coincided with the long daily peak period.[10] While turbines at the site will be affected by icing and dust, design and operating practices can ensure that performance and costs will not be affected substantially. Total economic capital costs for a 100 MW windfarm are estimated at Y 750 million, competitive with

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9 Eighty-three percent coal-fired and 13 percent oil-fired steam.

10 Windpower production pattern is based on Chinese estimates, applied to corrected production figures. Daily peak is 16 hours long, arguing an artificial supply-constrained demand.

costs worldwide ($900/kW, see Table 3.2).[11] However, because of the import duty on turbines, VAT and VAAT, the financial capital costs increase by a quarter to Y 945 million ($1,100/kW). Annual operating costs were estimated based on labor and materials, and are about 2.5 percent of capital costs.

TABLE 3.2: CHARACTERISTICS OF WINDFARM SITES

Input Parameters	Huitingxile	Nan'ao
Ultimate Potential (MW)	1,000	75-100
Windfarm Size (MW)	100	11.2
Wind speed (m/s)	8.8 (40m)	8.5 (6m)
Estimated Losses (%)	18	24
Annual Net Production (GWh)	335.1	33.5
Capacity Factor (%)	39	34
Avoided Energy Cost (Yuan/kWh)	0.32 (¢3.8)	0.30 (¢3.6)
Financial Price (Yuan/kWh)	0.43 (¢5.2)	0.46 (¢5.5)
Economic Capital Cost (Y million/$)	750 ($90)	89 ($11)
Financial Capital Cost (Y million/$)	945 ($114)	111 ($13)
Unit Economic Capital Cost (Y/$/kW)	7,585 ($915)	7,960 ($960)
Unit Financial Capital Cost (Y/$/kW)	9,560 ($1,150)	9,960 ($1,200)

Source: Study team estimates.

3.16 **Nan'ao Island**. This site represents the potential of windfarms to contribute to small island grids, where the wind resource is good and alternatives expensive. Nan'ao Island, 109 km^2 in area, is connected to Shantou city by 35 and 110 kV undersea cables. Shantou is on the Guangdong grid, which had an installed capacity at end-1993 of 14,005 MW (76 percent thermal and 24 percent hydro). Annual load growth is expected to be 13 percent to 2000, resulting in the installed capacity almost doubling to 23,164 MW.

3.17 This site has a good wind resource, measured at 8.5 m/s at 6 meter height.[12] Because the terrain is steep, the site may best be developed with machines in the 200 to 300 kW range. While the island grid is small at about 6 MW, including 4.8 MW of existing windpower, power can be sent to the mainland via submarine cables. The case study assumes an 11.2 MW windfarm installation at Nan'ao. Capital costs per kW installed are higher than at Huitingxile, losses are higher, and the capacity factor is lower at 34 percent.

3.18 Land is a constraint, limiting the potential for ultimate development to 75 to 100 MW. Careful siting of turbines is required, to maximize output from complex wind patterns. If the full potential were developed, intermittent windpower could have a

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[11] Costs were calculated assuming international competitive procurement.

[12] This estimate is based on a frequency distribution for Nan'ao by NREL, developed from handwritten data supplied by the SETC expert team. No wind shear has been assumed. For Huitingxile, data are based on frequency distribution supplied by SETC wind experts.

destabilizing impact on the Shantou local grid, indicating the need for a detailed feasibility study, including load flows and local grid stability assessments.

Benefit/Cost Analysis

3.19 The benefit/cost analysis is deliberately conservative, since there are uncertainties about installation costs, performance, startup times, operating costs of commercial windfarms on both sites.

3.20 **Economic Analysis**. Since there are no operating data to conduct a LOLP analysis, wind is given no capacity credit. The weighted-average avoided energy cost is Y 0.32/kWh for Huitingxile and 0.30 for Nan'ao (see Annex 4 for detailed calculations). The EIRR is estimated at 10 percent for Huitingxile and 5 percent for Nan'ao (see Table 3.3). Windfarms are near to being economically viable in Huitingxile, even under conservative assumptions that value power at the avoided energy cost only and assume a year is required for commissioning. According to the provisional data provided for the study, Nan'ao appears to be less attractive because it has higher capital costs/kW, a lower capacity factor and lower avoided energy cost. Many of the other sites in Table 3.1 would fall between these two examples.

TABLE 3.3: ECONOMIC AND FINANCIAL VIABILITY OF WINDFARMS

	Economic Internal Rate of Return (%, real)	Financial Internal Rate of Return (%, real)	Financial Internal rate of Return on Equity (%, current)
HUITINGXILE			
Base Case			
Today	10	10	13
2001	15	18	38
Sensitivity on Today			
No Duty, VAT	10	19	30
Capacity Credit = Capacity Factor	13	10	13
NAN'AO ISLAND			
Base Case			
Today	5	7	9
2001	8	11	15
Sensitivity on Today, 2001			
Today, no Duty, no VAT	5	15	22
2001, Capacity Credit = Capacity Factor	11	14	21

Source: Study team estimates.

3.21 With large-scale windfarm development in China, it is estimated that costs could be reduced by 20 percent within five years, through domestic manufacturing of turbine components and incorporation of international advances in technology. Commissioning times could be reduced to six months from one year. This would make future windfarms at Huitingxile economically viable at 15 percent EIRR, even without a capacity credit.

With cost reduction and a capacity credit equal to the capacity factor, Nan'ao Island would also appear to be close to economic viability at 11 percent.

3.22 **Financial Analysis**. Purchase prices for windpower from the two sites have been set at Y 0.63/kWh and Y 0.70/kWh, with no escalation, by the Inner Mongolian and Guangdong governments.[13] However, the real price over the 20-year life of the project in 1995 yuan is considerably less than the 1996 price, because of inflation. This levelized price is Y 0.43 for Huitingxile and Y 0.46 for Nan'ao. While these prices are 30 percent higher than the avoided economic cost, the increase only covers duties and taxes, which add 25 percent to capital costs in year 1, and similar amounts on operating costs.

3.23 Therefore, despite the higher financial price, the FIRR is similar to the EIRR at 10 percent for Huitingxile and 7 percent for Nan'ao. The financial rate of return on equity (in current terms) is estimated at 13 percent in Huitingxile and 9 percent at Nan'ao. The low financial return on windfarms is due to two factors: (a) import duties on turbines; and (b) the VAT and VAAT on capital costs. If the import duty and VAT were not charged, the Huitingxile site would be financially viable at 19 percent FIRR and 30 percent FIRREQ, while the Nan'ao site would also be viable (see Table 3.3).

3.24 If capital costs were brought down 20 percent from the base case by large-scale windfarm development and commissioning times decreased to six months, the Huitingxile FIRR would increase to 18 percent and the FIRREQ to 38 percent. At these rates of return, windfarms would be financially viable, especially because uncertainties about cost and performance at the site would have been reduced. Investors are looking for a minimum after-tax rate of return of 25 percent in China on conventional coal-fired power plants.[14]

Project Implementation Modes

3.25 Windfarm projects in China have been demonstration-scale, financed with low-interest loans and exempt from import duty, VAT and income tax. Subsidiaries of MOEP and the Inner Mongolian Electricity Management Bureau, the Beijing Fulin Wind Energy Development Corporation and the General Wind Power Company have led development in Inner Mongolia. A 26.5 MW windfarm is to be built by Xinjiang Windpower by late 1997, supported by a grant from the Dutch Ministry of Foreign Affairs.

3.26 Commercial-scale projects have not yet been implemented. They could be carried out by Chinese utilities alone, through joint ventures, or through independent power producer (IPP) arrangements that involve local ownership, foreign ownership, or both

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13 These prices are set by agreement among the Provincial Planning Commission, the Electricity Bureau, and the Price Administration Bureau in each province. They do not include VAT and VAAT, which have been added in the analysis.

14 See Paul L. Weber, "Negotiating a Power Plant Contract" in *The China Business Review*, November-December 1993, pp. 38-39.

(build, own, operate—BOO—and build, own, transfer—BOT). All BOT and BOO projects will require a power purchase agreement and other commercial contracting arrangements.[15] The Inner Mongolian government is attempting to attract large-scale investment, offering a favorable price and negotiable land tax, income tax, and future price arrangements. However, no such projects have yet been finalized.

Requirements for Commercial Windfarm Development

3.27 Reduction in costs and resolution of technical uncertainties, as well as policy and institutional changes, are needed before commercial-scale windfarm development will happen. Costs and technical uncertainties are discussed below, while institutional and policy issues are discussed in Chapter 4.

3.28 **Estimated Costs and Benefits**. Windfarms would yield more favorable returns, even at today's costs, if some of the parameters are proven to be different than assumed above. Because of the lack of commercial experience, all assumptions used in the analysis were conservative. Even today, installation costs could be lower, production startup could be faster, losses and operating costs could be lower. If performance data were available, a capacity credit could be justified and given in the economic assessment. The first large commercial windfarm on a site would answer many of the uncertainties about cost and performance.

3.29 **Medium-Term Potential for Cost Reduction**. In-country manufacturing and technology improvement are the keys to long-term economic and financial viability, since they are expected to reduce costs 20 percent by 2001. This could have worldwide implications, as China becomes a new market, equipment producer and eventually enters the export market. However, a phased program of in-country manufacturing of more complex parts (e.g., generators, gear boxes, controllers and blades) can only evolve in response to a dynamic, growing market within China. In India, installed costs per kW for windfarms have been reduced from $1,400 in 1991 to $1,100 in 1996, but the installed capacity also increased from 30 MW to an estimated 560 MW.

3.30 **Wind Resource Data**. For the sites examined, there was only one year of hourly wind data available, on paper. This makes analysis expensive, time-consuming and subject to error. The availability of wind data for the main sites needs to be improved by increasing the number of measuring sites, ensuring that equipment functions adequately, and using automatic measurement to reduce error. It would be an advantage to have data for several years, to assess interannual variability.

3.31 **Lessons Learned from Demonstration Projects**. While there are demonstration turbines at most sites, information is not easily available on their performance, operating experience, or their effect on local grid stability. Monitoring and reporting such

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[15] Agreements on land conveyance, ownership structure, construction, and operation and maintenance are generally required.

information would reduce uncertainty substantially. In addition, it would be possible to analyze the impact of the windfarm on the grid. Such analysis could provide a basis for giving windpower a capacity credit that would increase its economic viability.

Development Strategy

3.32 Windfarms have the largest potential to contribute significantly to power generation in certain regions of China, after small hydro. There are a number of sites in China that are world-class in terms of wind resources, logistics and access to a grid that needs the power. Windfarms are near to economic viability, even at today's costs and conservative estimates of avoided costs for alternatives. But, commercial windfarm development, at today's costs, including taxes and duties, is not financially viable.

3.33 A development program is needed, with the overall objective of laying the foundation for a sustainable commercially viable windpower industry in China. The program would have the following objectives: (a) installation of 100 to 200 MW of windfarm capacity at a site with large potential, such as Huitingxile, to demonstrate commercial viability, reduce costs by increasing local content, and resolve uncertainties; (b) development of domestic manufacture of key turbine components and their assembly in China; and (c) establishment of simplified and effective contractual and approval arrangements, that can be followed by future project developers. GOC investment and technical assistance for this program is a high priority.

D. SOLAR HOME SYSTEMS

Background

3.34 Photovoltaics systems are a least-cost, logical electricity source in many parts of northwestern China. These regions are characterized by excellent solar radiation, low temperatures, low population densities, large proportions of nomadic populations, rugged terrain with vast distances between towns and villages and limited transport systems. There were 2.2 million unelectrified households in such remote areas in 1994.

3.35 Providing electricity to these households is an important part of GOC's "8-7" program for poverty alleviation. In these regions, grid extension is usually not feasible. Diesel generators are used in some towns, but fuel supply and maintenance difficulties make them very expensive and unreliable. Recognizing the advantages of PV systems, the state and provincial governments are supporting their use for both dispersed and centralized power applications.

3.36 By 2000, GOC targets installation of 15 MW of PV for household use and 3.5 MW of centralized county and village PV stations, 11.5 MW for communications, and 1 MW of grid-connected PV. At the end of 1994, about 1 MW had been installed in China for household use, mostly 20 Wp systems for home lighting, radio and TV. The systems have been installed through the programs of the Rural/New Energy Offices that exist in 1,800 of China's 2,200 rural counties.

3.37 The nominal PV module manufacturing capacity in China is 5.5 MW per year, with six manufacturers accounting for 95 percent of production.. Actual production in 1994 was only about 1.2 MW. Module production costs are estimated to be about 10 percent higher than comparable costs overseas. This is because of outdated process technology, aging production equipment, low-capacity production lines, and unbalanced capacity of the production lines, particularly undercapacity in the wafer line. Rationalization of existing plants, and possibly investment in new facilities, is required.

Project Analysis

Project Description

3.38 Qinghai was selected for analysis of household solar home systems, as it represents other northwestern provinces with a large, dispersed population of herdsmen. Solar radiation is excellent with an average of 4.5 to 5.9 kWh/m^2/day, in southern and western Qinghai. There are 878 unelectrified villages and 107,000 unelectrified households in Qinghai. These areas are difficult to electrify because of the steep, broken terrain and the dispersed nature of villages. Households live in clusters that are grouped for administrative purposes into villages, but may cover tens and even hundreds of square kilometers. Population density is as low as 0.8 persons/km. The households move from their winter homes to summer homes on their grazing lands.

3.39 SHS are seen by the Qinghai Electric Power Bureau as the only viable alternative to electrify most of these households. Their plans indicate that more than 75 percent of the remaining unelectrified households will be served using PV (see Table 3.4). A local SHS industry has developed, including assemblers such as the Solar Energy Power Corporation of the Qinghai New Energy Research Institute, and 22 sales and service points that have been supported by the Qinghai Rural Energy Resources Office. The Qinghai Electric Power Bureau also has experience, with six remote towns and villages served by centralized PV plants (total installed capacity of 19.1 kWp).

3.40 The provincial government has introduced a surcharge of 0.2 fen/kWh on all electricity sales to finance electrification of poor households. This will generate Y 10.0 million in 1996, of which Y 0.9 million will be used to subsidize 3,000 SHS, at Y 300 per system, while the remainder will be used for grid extension, training, etc. The SHS program is limited by the size of the budget available to 15,000 systems, during the next five years. If the market was not limited by the amount of subsidy available for 20 Wp systems and the lack of credit, government officials estimate that 50,000 households could be targeted for PV electrification by 2000.

3.41 In 1995, sales surged to 5,000 units from 1,000 in 1994. The growing market for SHS indicates a willingness to pay for electricity by herdsmen families. The SHS purchase price after subsidy, at Y 1,400 for a 20 W system, is 14 times greater than the annual current household expenses for lighting and power. There is also a smaller market for larger systems of 50 Wp and 100 Wp, which is limited to wealthy households due to lack of credit.

TABLE 3.4: PLAN FOR HOUSEHOLD ELECTRIFICATION IN QINGHAI PROVINCE (HOUSEHOLDS ELECTRIFIED)

	1996-2000	2001-2010	2011-2020	Total
Grid extension	14,000	9,000	4,000	27,000
Centralized PV Plants (towns electrified)	7	25	-	31
Solar Home Systems	15,000	47,000	15,000	77,000
Small Wind	1,000	1,000	1,000	3,000
Total Households	**30,000**	**57,000**	**20,000**	**107,000**

Source: Qinghai Electric Power Bureau, *Electrification Plan to 2020.*

3.42 The subsidized price of Y 1,400 is the equivalent of about five "sheep units." This price is equivalent to the economic costs of a system today, or the financial costs of a system by 2001 including taxes, assuming that larger-scale production and technology improvement bring both better quality and lower cost. The current subsidy serves a dual purpose of increasing affordability and providing an incentive to purchase. It is seen as part of the Government's program to electrify poor households.

3.43 Government officials estimate that 20 percent of herdsmen households could afford a 20 Wp system without subsidy today. Within five years, this share could increase to 50 percent, as a result of increasing incomes and access to credit. If credit were available, the market could also be opened for larger PV systems (50 Wp and above) that can operate fans, televisions, sheep-shearing equipment, etc.[16]

Cost-Benefit Analysis

3.44 Grid electrification is difficult and uneconomic since most of the households are dispersed, move between winter and summer homes, and are more than 40 km from the grid. Diesel electrification is impractical because of the dispersion of the community, fuel transport difficulties, and the mobility of power source required. Since conventional alternatives cannot be used, a least-cost analysis against these options is not appropriate.

3.45 Therefore, the economic and financial justification is the demonstrated willingness to pay of the herdsmen. Households are paying only about Y 100/year for butter oil, kerosene lamps and dry-cell batteries. Their use is limited to about an hour a day because of the poor quality of service. With SHS, the households make a large upfront investment along with periodic expenditures to maintain PV components, and receive a wholly new level of service (see Table 3.5 for main parameters of the SHS). The households that have purchased SHS cite the following benefits: no indoor pollution; better quality and more

[16] Credit schemes are being offered in Qinghai that could be models for SHS. In Heka county, for example, the Agricultural Bank, Construction Bank and local credit unions are giving loans to households for water supply connections. The loans are given through village committees and township governments, which guarantee the loans.

hours of light, extending the day for living, studying, working; and use of the light to prevent sheep from straying in their summer pastures.

TABLE 3.5: MAIN CHARACTERISTICS OF SHS AND SERVICE PROVIDED

	20 Wp Systems	50 Wp Systems
Service Provided		
- Lighting—2 lamps (hrs per day)	4	4
- Other (kWh/day)	13	140
System Capital Costs (1995 yuan)		
Economic - Today	1,350	3,500
Economic - 2001	1,160	2,850
Financial - Today	1,600	4,605
Financial - 2001	1,400	3,380
Current Subsidy	300	-

Source: Study team estimates.

3.46 The net present value (NPV) of the life-cycle costs over a 15-year period of a SHS is compared to the costs of the alternative in Table 3.6. SHS costs include the capital cost of the system, annual replacement of the bulbs, replacement of the battery every two years and the controller every 10 years (see Annex 4). Costs of the alternative are Y 100 per year, on a financial basis, for purchase of lamps, kerosene and dry-cell batteries.

TABLE 3.6: ECONOMIC AND FINANCIAL LIFE-CYCLE BENEFIT/COST OF 20 WP SHS ON QINGHAI (NPV AT 12%)

		Benefits (1995 Yuan)			
	SHS Costs (1995 Yuan)	Avoided Costs Kerosene/Butter Oil Lamps, Dry-Cell Batteries	Government Subsidy	Willingness to Pay for Quality of Service	Total
Economic					
Today	2,300	645	250	1,400	2,300
2001	2,050	644	0	1,410	2,050
Financial					
Today	2,720	765	300	1,655	2,720
2001	2,435	765	0	1,670	2,435

Source: Study team estimates.

3.47 Economic and financial viability of SHS is demonstrated by the consumers' willingness to pay for improved service, in addition to these costs. By purchasing a SHS, households are demonstrating a willingness to pay an additional financial cost of Y 1,655, above the cost of the alternative and subsidy, on a life-cycle cost basis. In economic terms, the life-cycle willingness to pay for the additional service is Y 1,400.

3.48 The willingness to pay of consumers needs to be investigated further for both cash and credit sales of different sizes of systems. The role of the subsidy to the consumer also needs to be examined. Government officials felt that availability of credit could at least partially displace the subsidy.

Existing Institutional Arrangements

3.49 GOC has long and successful experience with rural mass promotion of technologies such as efficient fuelwood stoves, solar water heaters and small hydro. In Qinghai, the existing SHS project institutional structure provides a strong base for an expanded program. Principal responsibility for the Qinghai program is with the Qinghai Leading Group for Renewable Energy, which is chaired by the Vice Governor of Qinghai Province. The program is executed by the Rural Energy Resources Office at both the provincial and township levels.

Requirements for a Larger-Scale Market-Based PV Program

3.50 While the existing rural electrification program in Qinghai provides a good basis for a PV program, more market-based approaches are required for an expanded program, as described below.

3.51 **Increasing Affordability of PV Systems**. A larger market is needed to take advantage of economies of scale to reduce costs. Also, access to credit is needed to increase the affordability of the systems. Both factors will reduce or eliminate the need for a consumer subsidy on product sales to high- and medium-income families.

3.52 **Increasing Competition**. In Qinghai, there is little competition since only one supplier is eligible for the subsidy. Any future program must ensure that more than one supplier can participate in the marketplace, and that households have information on competing products and the freedom to choose among them.

3.53 **PV Industrial Sector Development Strategy**. There is a need to reduce the cost and improve the quality of locally manufactured PV modules. GOC has signed a number of Memoranda of Understanding to upgrade production lines and to increase output by more than 10 MW/year.[17] However, before embarking on an investment program, a sectoral development strategy is needed. Production equipment needs to be purchased under long-term technology transfer agreements. The severe shortage in silicon wafers needs to be addressed.

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[17] It is reported that SETC plans to retrofit one of the existing production lines to add another 1.5 MW of cell manufacturing capacity ($7 million). SSTC has signed a Letter of Intent with Amoco/Enron Solar Power Development in February 1995 to conduct a feasibility study for a 10-MW/year thin-film PV manufacturing facility and a 150-MW PV power plant ($290 million). Investments to improve production of existing manufacturing facilities and expand production to 8 MW/year from the 2.1 MW/year at present is planned at: Yunnan Semiconductor Device ($3.8 million); Qinhuangdao Huamei Photovoltaic Electronics Co. ($2.4 million); Ningbo Solar Electric Power Factory ($1.6 million); and Kaifeng Photovoltaic Factory ($1.6 million). Beijing General Research Institute for Nonferrous Metals, Qinhuangdao Huamei Photovoltaic Electronic Company are to construct a polycrystalline silicon PV plant to be located in Hebei Province ($10.6 million). Qinhuangdao Alpha Sunpower Co. plans expand manufacturing of PV concentrator collectors to 8 MW/year by 1998.

3.54 **Support for Research and Development**. Photovoltaic research funds from the Chinese Government have decreased in recent years and most PV laboratories have difficulty keeping their research facilities updated and retaining research scientists. Because of its promise in China, research funds need to be increased substantially rather than decreased. Also, it may be more efficient to focus national renewable energy research and development at key centers.

3.55 **Quality Improvement/Standards**. Developing or adopting internationally accepted standards for modules, components and systems and establishing a national center for module, components and systems testing and certification is needed. This will help to ensure quality control, which will expand the export market for Chinese-made PV products.

3.56 **Improving Access to Credit**. Lack of credit is a key constraint to establishing a larger-scale market-based PV electrification program. There is limited credit available to PV module manufactures and PV systems assemblers. Also, as noted above, lack of consumer financing makes the PV systems affordable only to the richest rural households.

3.57 **Expanding Distribution Channels.** There is a need to develop channels for marketing and servicing SHS in target areas. At the beginning, when sales volumes are low, this is expensive and may require government support for business development and technical training.

Development Strategy

3.58 There is good potential for a large-scale program to provide electricity to rural households through PV by developing a commercial market for solar home systems. The program would include the northwestern provinces with characteristics similar to Qinghai—dispersed and/or nomadic populations, large unelectrified areas, long distance between towns and villages, difficult transport conditions, limited energy supply options, good solar resources, etc. In some regions, such a program could also consider PV/wind hybrid systems and centralized PV-diesel hybrids.[18] The program can use the experience of GOC in promotion of rural technologies to design an appropriate mix of incentives and access to credit. Principal justifications for an expanded program are:

- Lack of other feasible alternative for majority of unelectrified households.
- Demonstrated willingness to pay for SHS that recognizes environmental and quality-of-life benefits.

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[18] In Inner Mongolia solar and wind resource availability is complementary—high winds in winter and excellent solar resources in summer. Household-scale PV/Wind hybrids are more appropriate than SHS in these areas. In Qinghai and Tibet with excellent solar resources, a large number of small townships that are far from fuel depots could be served more economically with PV-diesel hybrids. For a further discussion, see Section H—Other Technologies, in this Chapter.

- Demonstrated financial and policy commitment by state and provincial governments.
- High level of cooperation through the Rural Energy Leading Group and an organizational structure that could be adapted to support a larger-scale, market-based effort.
- Nascent manufacturing capability and sales and service networks that can be expanded.

3.59 The target market for these off-grid systems are the more than 2 million unelectrified households in the five northwestern provinces, especially the high- and medium-income households. Qinghai alone could support a program of 10,000 SHS per year for five years, for a total of 50,000 systems. Preliminary estimates from government officials and PV experts indicate that a SHS program aimed to serve 500,000 households, equivalent to about 12 MWp of PV, would be feasible (see Table 3.7). This estimate needs to be investigated further by detailed market surveys covering: the services required; the willingness to pay of customers; and preferred pricing and credit arrangements.

TABLE 3.7: PRELIMINARY ESTIMATE OF POTENTIAL HOUSEHOLDS TO BE SERVED BY AN EXPANDED SHS PROGRAM

Province	Current SHS Use (Number)	Unelectrified Households in 1994 (Number)	SHS Potential Over 5 years (Number)	PV Requirements (kWp)
Qinghai	10,000	107,000	50,000	1,500
Tibet	5,000	120,000	10,000	300
Inner Mongolia	7,000	536,000	100,000	6,000
Xinjiang	7,000	560,000	150,000	3,500
Gansu	3,000	832,000	200,000	400
Total	**32,000**	**2,155,000**	**510,000**	**11,700**

Note: Estimates of SHS potential from SETC PV Working Group members.

Source: Study team estimates.

3.60 **Implementation**. SETC could serve as the executing agency. Under its leadership, national and provincial PV Electrification Leading Groups would be appointed as advisory bodies. National and Provincial PV Electrification Project Offices would be set up. The existing rural energy/new energy offices would support work at the county level and below. The principal roles of the government agencies would be project coordination, financial management/oversight, supervision, monitoring and information dissemination. The suppliers would have primary responsibility for production, marketing, sales and service of the PV home systems (see Annex 3 for organization charts defining roles and responsibilities).

3.61 **Financial Requirements.** Assuming a 500,000 household (12 MWp) PV electrification project, the total project economic cost would be about Y 1,265 million over five years. Import duties and taxes would add Y 285 million to the cost (see Table 3.8). This estimate includes investment and working capital requirements for PV systems assemblers but not for upgrading PV module manufacturing facilities.

TABLE 3.8: PRELIMINARY ESTIMATE: FIVE-YEAR PROJECT INVESTMENT COSTS
(Millions of current yuan)

	Millions of Current Yuan
Loan to PV Systems Assemblers	
Equity	1
Investment Loan	4
Working Capital Loan	47
Subtotal	**82**
SHS	
Grants	218
Consumer Cash Purchase, Down Payment	965
Loan	281
Subtotal	**1,464**
Total (Rounded)	**1,550**

Note: Total cost includes Y 286 million in taxes and duties (Y 16 million in import duties, Y 43 million in income taxes and Y 227 million in VAT and VAAT).

Source: Study team estimates.

3.62 A SHS project is also a high priority for GOC assistance, because of its significant potential to lower costs for PV modules and broaden the potential market applications. If the 500,000 household PV electrification program were carried out over five years, it would create an additional market for PV modules of about 2.5 MW per year. Production of PV modules was only 1.2 MW in 1994, while nominal capacity was 5.5 MW. The additional volume of PV sales proposed will allow increased capacity utilization and rationalization of existing plants, or perhaps even investment in a new facility, which would have lower costs than the existing plants. Its impact in reducing PV module manufacturing costs should be significant, allowing China to bring costs down to international levels. This, in turn, would enable PV to be more competitive with alternatives in other applications.

E. BAGASSE COGENERATION

Background

3.63 Sugar production in China is centered in the southwestern provinces with Guangxi, Guangdong, and Yunnan Provinces accounting for 36, 27, and 14 percent of national sugarcane production, respectively, in 1993. There are shortages of power in Guangxi during the dry season (November to April). Power demand is growing rapidly in Guangxi, and the shortages are expected to continue until well after the year 2000. Since the dry season coincides with the cane milling season, bagasse cogeneration systems can generate excess power for the grid and contribute to electricity supply.

3.64 Cogeneration investments are particularly attractive since the state government plans to increase sugar production in the Ninth Five-Year Plan. Thirty-nine of the 100 sugar mills in Guangxi Autonomous Region will expand cane production and milling operations [from 2,100 tons of cane per day (tcpd) to 3,000 to 3,300 tcpd]. To process additional cane, the mills will have to purchase new machinery, including steam and electricity generating equipment. The expansion plans present an opportunity to make additional investments in equipment to generate surplus electricity (i.e., beyond plant needs), for sale to the grid. Since the cost of this equipment can be recovered from both sugar and power sales, the life-cycle costs of the power generation operation are low.

Project Analysis

Project Description

3.65 The analysis focuses on a typical bagasse cogeneration system at an existing sugar mill. Cane stalks are chopped to a uniform size, and soaked and pressed to extract cane juice. The cane juice is then subjected to a multistage evaporation process until sugar is crystallized. Pressed cane stalk (i.e., bagasse) is used as a boiler fuel to produce steam for evaporation and to generate electricity for the mill.[19] Historically, bagasse has had little value in Guangxi and energy efficiency was not maximized. The analysis assumes that all "excess" bagasse is used as fuel to generate electricity for sale to the grid.

3.66 The project involves the expansion of an existing sugar mill from 3,000 tcpd to 5,000 tcpd, and the associated installation of equipment that will generate surplus electricity for sale to the provincial grid. Existing expansion plans include the purchase of equipment to meet in-plant energy needs only; generation of surplus electricity is not planned. Milling operations are assumed to occur 24 hours/day during the 180-day milling season (November through April).

[19] Although it is common practice to operate mechanical equipment (e.g., pumps, cane shredders, conveyors) with steam turbines, the current practice in China is to use electric motors.

TABLE 3.9: TECHNICAL PARAMETERS FOR BAGASSE COGENERATION CASE STUDY

	Existing Mill	"Without project" Mill Expansion	"With project" Mill Expansion
Mill Capacity (tcpd)	3,000	5,000	5,000
Excess bagasse (% of total)	10%	10%	0%
Boiler Capacity (tph)	75	75 (existing) + 50 (new)	75 (existing) + 75 (new)
Boiler Pressure (MPa)	2.4	2.4	2.4 (existing) + 4.9 (new)
Capacity to Grid (kW)	0	0	9000
Power to Grid (GWh)	0	0	315
Turb./gen. cap. (kW)	5,000	5,000 (existing) + 3,000 (new)	5,000 (existing) + 9000 (new)
Turbine type	Back pressure	Back pressure	Back Pressure (existing) + Condensing Extraction (new)

Source: Study team estimates.

Cost-Benefit Analysis

3.67 The primary expenditures associated with the bagasse cogeneration system are the capital costs of the boilers, turbines, and generators. In the "with project" case , about 70 percent of the capital expenditure is allocated to the production of excess electricity for grid sales; the remainder of the costs are allocated to sugar production. This is conservative, as international experience has shown that less than 50 percent of capital expenditures can be attributed to generation of surplus electricity. As only 20 percent of sugar mills in Guangxi sell "excess" bagasse, the analysis does not include opportunity costs for bagasse.

3.68 **Economic Analysis**. The avoided cost of power generated by the bagasse cogeneration system is derived from a weighted average of (medium-voltage) peak, mid-peak, and off-peak avoided capacity, energy and network costs during the dry season, on the Guangxi grid (see Annex 4). The facility is given a fuel capacity credit as the bagasse plant provides power during the dry season when there is a shortage of capacity. The resulting avoided cost is Y 500/MWh. Using this figure and the economic costs listed below, the EIRR for the case study facility is 33 percent, indicating that the project is particularly beneficial.

TABLE 3.10: ASSUMPTIONS FOR ECONOMIC/FINANCIAL ANALYSIS

Cost Component	Units	Economic	Financial
Incremental Capital Cost	'000 yuan	36,500	42,725
O&M Cost	% of capital cost		
Excess Electricity Sold	GWh/year	31.5	31.5
Total Revenue	'000 yuan	15,735	21035
Avoided Cost/Power Price	yuan/MWh	500	510

Source: Study team estimates.

3.69 **Financial Analysis**. A pretax power purchase price of Y 510/MWh (excluding VAT on power sales) is required to achieve an FIRR of 20 percent. This required price is near the economic avoided cost, at Y 500/MWh, and well within the Y 500 to Y 600/ MWh range, which the Guangxi Power Bureau indicated it is willing to pay to for power from bagasse cogeneration, indicating that the project is financially viable at current costs.

Estimate of Potential

3.70 The Ninth Five-Year Plan aims to increase sugar production in China from 6.2 million tons in 1995 to 10 million tons per year by 2000. The 100 mills in Guangxi account for approximately one-third of the planned increase. By extrapolating the analysis to the 39 mills identified for expansion in Guangxi, it is estimated that 350 to 450 MW of surplus power can be generated. This potential matches Guangxi's estimated 400 to 500 MW dry-season supply deficit. Although the mills in Guangxi represent one-third of sugar production capacity in China, these mills are estimated to represent one-half of the total national potential for surplus power. The national potential for surplus power from the sugar industry is, therefore, 700 to 900 MW today. As sugar production continues to increase, this potential will also increase.

Requirements for Development

3.71 **Access to Capital**. Access to capital is currently limited to that for "in-plan" mill expansion from agricultural banks, which lend on three- to five-year terms at 12 percent interest. Neither the agricultural banks nor the other financial sources available to the sugar companies can fully support the existing borrowing requirements of the sugar industry. Without longer-term debt financing at commercial interest rates, surplus power projects at sugar mills will not proceed and the potential for bagasse cogeneration for supply to the grid will not be realized.

3.72 **Institutional Considerations**. Because expansion plans for the 39 identified mills in Guangxi are currently being implemented, some of the potential may be forgone. There is urgent need for action to take advantage of this opportunity. Such action will require close coordination between local, provincial, and state institutions including sugar mills, the Provincial Power Bureau, the Guangxi Economic and Trade Bureau (responsible for power dispatch), and SETC (potential financing source for renewable energy commercialization projects). In the very short term, a surplus power component should be added to one mill to provide a commercial demonstration of the technology and to prevent further missed opportunities.

3.73 **Technical Assistance**. The following technical assistance is required:

- Assessment of feasibility for increased cane productivity, introducing new cane species (higher fiber content, improved disease/drought resistance). Fiber content is only one of several factors to be considered in evaluating new species.

- Evaluation of the impact of extending the milling season (to maximize surplus power) on the cost and quality of sugar production.

- Evaluation of alternative cogeneration system designs, including instrumentation and control improvements to coordinate sugar production and surplus power generation; improved boiler/steam turbine designs; and steam turbines mechanical drives.

- Training of plant personnel to operate and maintain new bagasse cogeneration designs.

- Development of a standard power purchase contract to reduce transaction costs. This is important as sugar mill owners will not be familiar with the power business.

Development Strategy

3.74 **Investment**. Because mill expansion is underway but capital is not available to the mills for cogeneration investments, GOC assistance is urgently needed to finance an initial surplus power bagasse cogeneration project. While the availability of suitable boilers and other equipment in China needs further investigation, the technology and operating practices required are well proven in the rest of the world. Cogeneration investments are economically and financially very attractive. Demonstration of the technology in an existing mill is the first step required. The industry will also require access to long-term debt financing (e.g., 10-year terms). Mill owners would need Y 2.2 billion in order to develop 350 MW of surplus power. In addition, assistance is needed to develop power purchase agreements and deal with grid integration issues.

F. BIOGAS POWER

Background

3.75 With more units than any other country (approximately 5.5 million), China has extensive experience in household-scale biogas digesters to provide fuel for cooking. Biogas technology development is supported by a network of research centers and a manufacturing capacity for anaerobic digesters and associated equipment. There is less experience, however, with the use of biogas for power generation, particularly for grid-connected systems. Although China has extensive capacity for manufacturing diesel engines of the capacity suited for grid-connected biogas power facilities (300 to 1,000 kW), fewer than 100 such facilities exist.

3.76 Pig and chicken farms are the major sources of biogas feedstock. While approximately 90 percent of pork production in China occurs at either the village or household level, agricultural operations are becoming increasingly consolidated. Many large livestock farms do not invest in effluent treatment, and surface and groundwaters are subject to discharges with organic contents exceeding state and international standards.

Farms with biogas digesters generally use the gas for process heat, on-site cooking, and/or distribution to nearby households (for cooking and, to a lesser extent, lighting). Electricity production from biogas in livestock farms has recently become more important as (a) farms have increased in size and been forced to locate far from residential areas, hence generating more gas than can be used locally; and (b) public sensitivity to pollution issues has increased. A 600,000 pig farm at the Pudong development zone near Shanghai, for example, is reportedly planning a biogas project that would export 5 to 10 MW to the grid.

3.77 The use of biogas for power production, the economics of which are examined below, is by no means the only important application of biogas technology in China. The anaerobic treatment of industrial (e.g., distillery) effluents to reduce chemical oxygen demand (COD) and the use of the biogas produced for process heat in the plant, in particular, is an application that has tremendous potential for energy production and environmental management. This application is examined in the parallel study on thermal-related renewable energy development.

Project Analysis

Project Description

3.78 The Beijing Municipality was selected as the site because over 75 percent of the region's pig farms are intensive (i.e., greater than 1,000 pigs), and nine farms, each with 6,000 or more pigs (six farms with a scale of over 10,000 pigs), are planned over the next five years. These plants are in proximity to the JJT grid where the utility has agreed to purchase the electricity. The project evaluated involves the thermophilic anaerobic digestion of waste from 15,000 pigs at a livestock farm in the Beijing Municipality. By heating the waste to 55°C (via coal combustion), thermophilic digestion allows waste to be processed faster than conventional methods, thereby reducing digester size and cost. In addition, by permitting constant gas production independent of ambient temperature, thermophilic digestion allows the biogas power facility to be fully dispatchable and receive full generation capacity credits.

3.79 Waste generated by livestock is sluiced and fed into an anaerobic digester to produce biogas, which is stored, then released to generate electricity for eight hours during the peak period. It is assumed that 10 percent of all gas produced is sold to homes in proximity to the livestock operation. In addition, fertilizer is produced and sold for field application. Table 3.11 shows the primary technical assumptions for the analysis (see also Annex 4).

3.80 If discharged to the environment untreated, biodegradable organic compounds in the waste stream will stabilize and potentially lead to depletion of natural oxygen resources and the development of septic conditions. It assumed that organic matter in the waste stream (measured in milligrams/liter—mg/l—of COD) is reduced by 90 percent by the anaerobic digestion process. However, because the organic content of the digester effluent exceeds the 300 mg/l surface water discharge limit set by the National

Environmental Protection Agency (NEPA), the case study design also includes an aeration system.

TABLE 3.11: ASSUMPTIONS FOR BIOGAS CASE STUDY ANALYSIS

Technical Assumptions		Economic/Financial Assumptions	
Pigs (head)	15,000	Financial Capital Costs ('000 yuan)	2,990
Total Gas Produced (m^3/yr)	700,000	Financial Operating Costs ('000 yuan/yr)	420
Net Power Generated (MWh/yr)	911	Financial Revenue - Electricity ('000 yuan/yr)	515
Gas for Household Use (m^3/yr)	70,000	Avoided Costs (yuan/MWh)	575
Fertilizer Produced (tons/yr)	2,000	After-tax power purchase price (yuan/MWh)	500
COD before digestion (mg/l)	15,000	VAT on Inputs (%)	17%
COD after digestion (mg/l)	1,500	VAT on Outputs	0%
COD after aeration (mg/l)	300	VAAT on VAT on Outputs	n.a.

Source: Study team estimates.

Cost-Benefit Analysis

3.81 Costs for the biogas facility are given in terms of capital and operating expenditures; revenue is generated from the sale of electricity, fertilizer, and biogas.

3.82 **Economic Analysis**. The calculated EIRR of 18 percent indicates that a biogas power project at a 15,000 pig farm and connected to the JJT grid is economically beneficial. In fact, economic viability is attained at projects as small as 10,000 pigs.

3.83 **Financial Analysis**. Because anaerobic digestion of animal waste is considered a recycling process, the revenue from its products is not subject to VAT. Income from electricity sales is based on a power purchase price of Y 500/MWh as agreed upon by MOEP. This price is less than the economic avoided energy and generating capacity costs during the peak demand period. The FIRR in real terms is calculated to be only 5 percent, indicating that a biogas power project at a 15,000 pig farm will not be attractive to investors, under these conditions.

3.84 **Sensitivity Analysis**. Under "base case" conditions, a scale of 50,000 pigs is required for financial viability. Although all of the variations listed below lower the scale required to achieve the target FIRR, financial viability is not achieved at the size of most piggeries today (i.e., less than 10,000).

- Power purchase price equal to avoided costs (Y 575/MWh). Break-even: 40,000 pigs.
- Diesel engine generator efficiency—assumes 32 percent efficiency. Break-even: 35,000 pigs.
- Inclusion of current (low) environmental discharge penalties. Break-even: 46,000 pigs.

- All of the above. Break-even: 26,000 pigs.

Estimate of Potential

3.85 If it is assumed that only 10 percent of the live weight produced outside of rural households is in farms with over 10,000 pigs (as estimated by Chinese experts), the total economic potential would be approximately 100 MW. Given prevailing conditions, only at farm sizes above 50,000 pigs will biogas power be profitable to investors. Without detailed farm-size distributions, it is not possible to estimate the total biogas power capacity likely to be installed in the next five years. But it is clear that as livestock operations continue to be consolidated, more financially viable opportunities will emerge. The proposed 5 to 10 MW, 600,000 pig farm in Shanghai will be certainly be one of these initial opportunities.

Requirements for Development

3.86 **Financing**. Low-interest loans are available for biogas facilities. However, significant investment in grid-connected biogas power plants is not likely at this time as it is financially attractive only for very large animal farms.

3.87 **Enforcement of Environmental Regulations**. As a matter of policy, it is clearly important to curtail discharges of organic wastes from all livestock operations regardless of farm size and treatment process. This is particularly true for large husbandry operations where the effects of uncontrolled discharges are especially acute. NEPA needs to reexamine its current schedule of fines to heavy polluters in animal farms with a view toward setting more appropriate fines, thereby encouraging investments in biogas treatment facilities.

Development Strategy

3.88 Opportunities for investments in large-scale, grid-connected biogas power plants investment should be actively identified and encouraged. Such opportunities are expected to increase as husbandry operations continue to become consolidated. Transfer of the latest technology in materials, and plant and engine designs from other countries for power production from biogas should be sought by GOC.

G. GEOTHERMAL POWER

Background

3.89 China is a global leader in using geothermal resources for direct heat applications, with a thermal power contribution of over 2000 MW_{th} and a thermal energy production of over 5,000 GWh in 1990. However, geothermal power facilities are limited to a few demonstration sites, due to incomplete resource assessment and limited power demand in areas with high-temperature geothermal resources. Presently, only 30 MW of power generating capacity exists, including a 25 MW plant in Yangbajain, Tibet. High-temperature resources (i.e., >100°C) exist in the East Taiwan Geothermal Zone, which lies along the southeast coast; and in the Yunnan-Tibet Geothermal Zone, located in the southwest plateau and including southern portions of Tibet and western portions of Yunnan and Sichuan Provinces.

3.90 The objective of this assessment is to evaluate the status of knowledge about the potential for geothermal resources to meet the power requirements in western Yunnan and Tibet and recommend a resource assessment plan. One specific focus is a geothermal field in Tengchong County, Yunnan Province with excellent resource potential.

Geothermal Project Analysis

Geothermal Development in Tengchong County

3.91 Tengchong County is located in the Baoshan Prefecture in southwest Yunnan Province and has a population of approximately 530,000. Power demand is dominated by the county's 140 industries. However, due to difficult terrain, electricity in Tengchong County is provided from an isolated network with 13 MW of small hydro capacity. During the dry season, the hydro capacity drops to 50 percent of rated capacity. There is significant suppressed demand, and 11 MW of captive generating capacity exists from small-hydro and diesel-engine generators.

3.92 The geothermal resource measurements at the Rehai geothermal field in Tengchong County indicate that it is probably the largest geothermal system, not only in China, but in the entire Himalayan geothermal belt extending from northern Pakistan through Tibet to northern Thailand. Surveys at the Rehai field suggest a subsurface reservoir of about 10 km^2 with full, at-depth equilibrium temperatures of approximately 230°C. This field could support up to 100 MW of electricity generation over 30 years. Additional measurements are required to determine the area and a conceptual model of the field.

3.93 However, the full potential of the Rehai field may not be achievable without affecting the Rehai hot springs, which are a valued tourist attraction. A smaller 10 MW geothermal plant could be feasible without significantly affecting the hot springs. Regardless of the resource potential, initial development of the Rehai geothermal field may be limited by the local power network; currently the grid has the capacity to transmit and distribute 10 MW_e of power above current levels.

Geothermal Development in Tibet

3.94 While the high-temperature geothermal resources in Tengchong County can be attributed to solidified magma stranded in the earth's upper crust, the majority of the geothermal systems in the Himalayan belt are more likely due to water that penetrates the earth's structure to unusually great depths and rises to the surface with temperatures of 160°C ± 70°C. While there appears to be approximately six fields in Tibet with natural thermal outputs, their power generation potential is generally less than 10 MW per field.

However, these resources in Tibet are located far from industrial load centers.[20] Therefore, a strategy for broader use of geothermal energy for power production must focus on efficiently identifying, characterizing and economically developing sites with small 1 to 2 MW plants.

Requirements for Development

3.95 **Tengchong County**. Before Rehai field development, more extensive geoscientific studies would be needed to better define the reservoir, prepare the prefeasibility study and identify possible exploration- and production-well drilling sites. About three exploration wells are needed to locate a high-temperature resource, measure the resource temperature, characterize geothermal fluids, and estimate productivity of wells. Local and provincial authorities have estimated the cost of such exploratory drilling to be Y 25 million, and are currently seeking financing. A detailed feasibility study is also needed.

3.96 **General Geothermal Development**. Past geothermal resource development experiences indicate that more extensive and advanced geoscientific investigations and use of advanced field modeling techniques are needed prior to actual drilling. For example, over 40 exploration and production wells were drilled for the 25 MW facility in Yangbajain. Similarly, 13 wells were drilled at Langjui hot springs and two 1 MW generators were installed and in Nacqu, 20 exploration wells were drilled to support the eventual installation of a 1 MW_e binary power facility. With drilling costs exceeding Y 8 million per well, such practices are not advisable.

3.97 The technically and economically feasible electric potential of all geothermal resources in Tibet and western Yunnan Province may be 200 to 500 MW. To realize this potential within the next 10 to 20 years, all major hot spring occurrences need to be reexamined, taking into account both resource potential and demand for power. Due to the remote location of many geothermal manifestations, the absence of reliable year-round power supply, and the issues encountered with previous geothermal developments, special attention must be given to demonstrating the feasibility of geothermal plants with capacities of 1 to 2 MW and to developing a strategy for efficiently implementing projects of this scale.

Development Strategy

3.98 Technical assistance is needed to assess the feasibility of developing the Rehai field. Assistance is also needed to support broader geothermal energy development in the Tibet-Yunnan Geothermal Zone. Investment funds would be needed to develop the Rehai geothermal steam field and the associated power plant, if warranted.

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[20] For example, power demand in Lhasa (population 100,000) is principally residential loads and the grid-connected 25 MW Yangbaijing geothermal power plant has a capacity factor of only 45 percent as it is used to meet the daily peak residential power demand.

H. Other Technologies

3.99 In addition to the renewable energy systems selected for detailed analysis, there is interest in other technologies in China including solar thermal, small wind and wind hybrid systems, biomass power technologies beyond bagasse cogeneration. The following provides a summary of the experience with these technologies in China, and recommendations to foster their development.

Wind and PV Hybrid Systems

3.100 There is noteworthy experience with off-grid wind generators with capacities under 5,000 W each, in Inner Mongolia and other northern and western provinces. In addition, China has demonstrated village-scale wind/diesel and wind/PV/diesel hybrid systems. Currently, over 140,000 stand-alone wind turbines with a total capacity of 17 MW are operating. Most are used by nomadic herdsman and individual homeowners in remote regions to power fluorescent lighting, televisions, and other small consumer electronic systems. The Inner Mongolia New Energy Office supports purchase of these systems with a Y 200 subsidy per 100 W wind generator. The subsidy covers 20 percent of total cost and is responsible for increasing demand over the past 10 years. Seventeen of China's 40 manufacturers of small wind generators are in Inner Mongolia.

3.101 In Inner Mongolia, due to the complementarity of wind and solar resources, wind-PV hybrids may offer improved service over stand-alone wind or PV systems. Such household-scale wind/PV hybrids could be considered as part of a larger-scale off-grid electrification project to serve some of the more than 500,000 unelectrified households in Inner Mongolia.

3.102 The provincial power bureaus in Qinghai and Tibet are installing village-scale PV-diesel hybrids to serve isolated and remote towns. There are five such systems in Qinghai and by end-1996, eight in Tibet. Their power output is 0.6 kWp to 25 kWp and some have been in successful operation since 1990. A typical system consists of a PV array, diesel-backup generator, control and power conditioning equipment and a distribution network. The principal advantage of the PV-hybrid system over a diesel-only system is that diesel fuel requirements are minimal and maintenance costs are low. A PV hybrid can provide 24-hour power without efficiency or reliability losses associated with part-load operation of diesels, especially in the high plateau areas in Qinghai and Tibet. Such systems are, therefore, most appropriate for towns that are far from fuel depots and difficult to access.

3.103 Preliminary economic analysis for a 100-household town in Qinghai shows that at today's costs, a PV-diesel hybrid is least-cost compared to a diesel-only alternative when delivered fuel cost is Y 3.50/kg (equivalent to transporting fuel 3,000 km by road from a fuel depot). By 2001, the break-even cost of fuel drops to Y 2/kg (500 km transport distance). There are many such towns in Qinghai and Tibet that are 500 km and more from main fuel depots. However, on a financial basis, the current residential tariff (under

Y 0.5/kWh) will not make the PV-diesel hybrid (or even diesel-only system) financially sustainable without additional support from the provincial government.

3.104 Further evaluation of PV-diesel hybrids should assess competitiveness vis-à-vis solar thermal dish Stirling technology, which may reach commercial maturity by 2000. It is recommended that PV-diesel hybrids be considered as part of a broader off-grid electrification program involving SHS and PV-wind household hybrid systems.

Biomass Power

3.105 Beyond the conversion of biomass wastes to power in animal husbandry and sugar mill operations, there may exist other opportunities for power production from other types of agroindustrial residues in China. Recent estimates indicate that some 600,000 tons of biomass residues are produced annually (Table 3.12)

TABLE 3.12: ESTIMATED ANNUAL BIOMASS PRODUCTION IN CHINA

Type of Biomass	Quantity, '000 tons	TCE/'000 tons	Percent
Straw	549.72	273.78	91
Forest residues	36.00	21.00	7
Rice Husks	6.30	3.42	1
Bagasse	6.00	3.00	1
Total	**598.02**		**100**

Source: Study team estimates.

3.106 However, most of these resources are used to meet residential and industrial energy needs. The remainder, although considerable, are highly dispersed. Consequently, the predominant use of biomass resources will continue to be in small, home or village-scale, applications, such as cooking with rice straw, biogas production in family-size digesters, or biomass gasification for process heat in small industries. There appears to be considerable experience on small biomass gasifiers using wood wastes and rice husks. The designs are simple but suited to rural applications where low capital cost is more important than top performance. Ongoing efforts to disseminate these appropriate technology devices should continue to be encouraged.

3.107 For large-scale conversion to energy, applications will be limited to "captive waste" situations, e.g., bagasse in sugar mills or dung in livestock farms, as discussed in the case studies. Even in such situations, it is best to utilize proven technologies and wait until emerging large-scale biomass power systems have been commercialized. The 30 MW Biomass Integrated Gasification/Gas Turbine (BIG/GT), for example, that is proposed in Brazil appears promising. However, its potential relevance to China is questionable given the lack of gas resources and the enormous amounts of biomass (over 2,000 tons per day) needed to sustain its operation. A solution that has been proposed is the establishment of vast areas of dedicated plantations of fast-growing biomass to support modern large-scale gasification or direct combustion power systems. The experience worldwide with such schemes is still very limited and, except, for feasibility studies, is not recommended for investment action at this time.

Solar Thermal Power

3.108 Parts of China, particularly the northern and western parts, have abundant direct normal insolation that is potentially attractive for solar thermal power plants. The three technologies most commonly included within this definition are parabolic trough devices, central receivers and parabolic dish systems. Of these three, parabolic trough devices are already in commercial use in the United States. A total of 354 MW of capacity was installed using this technology in the Mojave Desert in California in the 1980s and early 1990s and the systems are still in use. Parabolic dish systems, driving gas engines or Stirling engines in the 5 to 100 kW range, are nearing commercial production. Central receivers are still at the demonstration stage and it is unlikely that the technology will be commercially viable before 2000 at the earliest.

3.109 In 1993, the Ministry of Energy and the United Development Incorporated, Ltd. completed a prefeasibility study of a 35 MW solar thermal power (STP) facility using parabolic trough technology in Lhasa, Tibet. The plant was proposed to operate in a solar-mode only with generated electricity used at a future pumped storage hydropower facility. The capital cost was estimated to be about $100 million and the levelized energy cost (LEC) around 30¢ per kWh. The study is regarded more as a technical exercise than a practical solution. The Yangbajain geothermal power facility that is connected to the Lhasa network is underutilized (45 percent capacity factor; see Geothermal Power section) so there is no apparent need for the STP facility.

3.110 What the study demonstrated was the technical feasibility of using an STP with a pumped storage scheme, indicating that similar situations elsewhere in the country should be studied. The Lhasa scheme, however, uses the old Solar Electric Generating Stations (SEGS) design, which is now being displaced by the more efficient Integrated Solar Combined-Cycle Systems (ISCCS) that integrates the solar parabolic field with a gas-fired combined-cycle plant. Utilizing new combustion turbines, the ISCCS can achieve effective efficiencies exceeding 60 percent, compared to the 39 percent obtainable from the SEGS Rankine-cycle operation. This is seen as the key to dramatically reducing the levelized energy cost of parabolic-trough solar-thermal power plants.

3.111 The ISCCS hybrid scheme would seem to have limited applicability in China since natural gas is not widely available. Hybridizing solar thermal with coal plants is technically possible, but analytical and hardware testing on this combination lags that for gas of fuel oil hybrids. A recent preliminary analysis done by Sandia National Laboratory[21] indicated that, provided certain integration issues (e.g., need for nonstandard boiler design) are resolved, solar thermal/coal hybrid plants can be as viable as hybrids with natural gas or

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[21] Greg Kolb, Communications with the World Bank, January 1996.

fuel oil. Due to the importance of coal for power generation in China in the future, it is recommended that technical assistance be provided to study the technical and economic feasibility of parabolic-trough solar-thermal/coal hybrid power plants in selected sites.

3.112 As regards parabolic-dish/Stirling-engine systems, a watching brief should be maintained on the impending commercialization of systems in the 25 to 50 kW capacity range. Their relative simplicity of installation, high efficiency (25 percent) and modularity make them suitable for remote-power applications in areas of China with high direct normal insolation. The forecast for the year 2000 when the systems are expected to be in volume production in the United States (about 5,000 units per year) is for installed costs to drop to about $2,000, at which level they will be competitive with most alternatives for distributed power.

Small Hydropower

3.113 As of 1993, over 15,000 MW of generating capacity was installed at over 48,000 small hydropower stations in China. The vast majority of this capacity lies in southern provinces and has been developed as a result of a series of Government-sponsored programs and policies. Underpinning development is a network of local manufacturing facilities and trained personnel (construction, operation, and maintenance) following standard designs and practices. As is the case with coal-fired facilities, China currently produces its own hydroelectric equipment, and has a proven capability in the design and engineering of large and small hydropower projects.

3.114 Recognizing the success of SHP development efforts and the role that the technology plays in meeting power demand, the Government has established plans to increase the installed capacity of SHP facilities by over 30 percent (from 15.1 to 19.9 GW) by 2000 and by 85 percent (to 27.9 GW) by 2010. However, current SHP programs and practices need technical assistance and support from GOC to address the following problems:

(a) **Improve Equipment Quality**. While local manufacture of turbines has had many advantages, SHP equipment in China is less automated and less efficient than Western-made machines. Technology transfer could be of great assistance in improving performance and lowering the number of staff required to operate the stations.

(b) **Reduce Transmission and Distribution Losses**. Poor-quality transmission and distribution lines, low power factors, and other factors have led to high losses.

(c) **Improve Station Design and Regulatory Capacity**. Most SHP systems built were run-of-river, with excess installed capacity and a low capacity factor.

(d) **Improve Economic Evaluation**. SHP stations need to be subject to better review of economic benefits and costs before being built. Some SHP systems have had high costs in relation to output, thereby burdening local communities.

(e) **Rationalize Prices**. Because many SHP stations were developed prior to reform in the power sector, the power purchase price has not kept pace with SHP station costs. GOC needs to evaluate and rationalize SHP prices, in relation to reform in the power sector.

I. ENVIRONMENTAL BENEFITS FROM POWER-RELATED ENERGY TECHNOLOGIES

3.115 Renewable energy projects in China will generate immediate environmental benefits by offsetting power generation from existing coal- and oil-fired power plants, by deferring the need for new power plants or hydroelectric dams or, in the case of photovoltaic solar home systems, by offsetting indoor kerosene combustion and battery use. Over the longer term, these projects will generate increasing environmental benefits by developing the market for renewable energy in China. This section provides an overview of these avoided environmental impacts (see Annex 2 for more detail).

Avoided Local Environmental Impacts

3.116 Renewable energy projects will offset air, water and land impacts of thermal power generation, indoor kerosene combustion and battery usage. Offsets of air emissions are the most significant impact, benefiting human health. Coal- and oil-fired power plants and kerosene lamps emit particulates, sulfur dioxide, nitrogen oxides, toxics and other compounds that are hazardous to human health and local ecosystems.[22]

3.117 Data from the Chinese Ministry of Public Health indicate that chronic obstructive pulmonary disease, which has been linked to exposure to fine suspended particulates and sulfur dioxide, was the leading cause of death in 1988, responsible for 26 percent of all deaths.[23] While some of these deaths can be partly blamed on smoking and other behavioral factors, air pollution has a major impact on human health in China. GOC has reacted by making the improvement of air quality one of its major objectives in China's Agenda 21, its 1994 white paper on environment and development. These considerations

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[22] Particulates aggravate preexisting heart and respiratory illnesses and, over the long term, contribute to chronic respiratory disease, cancer and premature illness and death. Sulfur dioxide causes constriction of the airways in asthmatics and other sensitive individuals and, over the long term, leads to chronic bronchitis. Particulates and sulfur dioxide also react together to form hazardous acid sulfate particles, which are inhaled deeper into the lungs where they cause damage. Nitrogen oxides damage the cells lining the lungs and, over the long term, cause changes in lung structure and function resembling emphysema and chronic bronchitis. Both sulfur dioxides and nitrogen oxides convert into acids in the atmosphere and lead to acid rain and dry deposition, which harm plants everywhere and animals in affected water bodies. Finally, toxics emitted by coal- and oil-fired plants cause cancer and other human illnesses.

[23] World Bank, 1992, *China Environmental Strategy Paper*, p. x.

demonstrate that the incremental contribution to ambient air pollution from thermal power plants and kerosene lamps is an important issue in China.

3.118 Table 3.13 provides estimates of avoided air emissions as a result of the renewable energy case study projects analyzed in this report. The figures for the first four projects are based on avoided generation from coal- and oil-fired power plants fitted with pollution control equipment.

TABLE 3.13: AVOIDED AIR EMISSIONS
(tons per year)

Project	Capacity	Annual Production (GWh)	Total Suspended Particulates	Sulfur Dioxide	Nitrogen Oxides	Toxics
Wind-Inner Mongolia	100 MW	335	420	1,240	670	10
Wind-Guangdong	11 MW	33	120	210	60	1
Bagasse-Guangxi	9 MW	31	130	240	70	2
Biogas-Beijing	1 MW	1	0	2	2	0
PV-Solar Home Systems	400,000	n/a	n/a /a	90	n/a	n/a

/a TSP emissions from kerosene lamps are not available but would be high.

Source: Study team estimates.

3.119 The renewable energy case study projects will also avoid water and land pollution associated with thermal power plants, kerosene combustion and battery usage.

3.120 It is difficult to compare quantitative and qualitative information regarding local environmental impacts with economic costs and benefits of energy resources. One way to overcome this problem is through valuation. Once environmental impacts are converted into monetary values (yuan or dollars), they can be easily compared with economic factors.

3.121 Uncertainty and controversy surround the valuation of residual environmental impacts, arising from a variety of methodological steps and assumptions that are still the subject of debate in this new area. Nevertheless, this uncertainty and controversy must be viewed in the context of the conventional alternative, which is to value these effects at zero. Given the documented linkages between fossil fuels and damages to human health and climate change, this is clearly incorrect. The challenge therefore is to calculate positive values for environmental impacts that are broadly right, rather than accept a zero value that is clearly wrong.

3.122 In order to estimate the order of magnitude of the avoided local air emissions in Table 3.1, they were valued using proxy externality values derived from studies in China and the United States.[24] These externality values are based on linkages between air emissions and air pollution and, in turn, between air pollution and human health effects. A high and low set of values were used to establish a range within which actual values might reside (see Annex 2 for details). These values and the resulting estimates of environmental benefits are indicative only. Further research and analysis is required to generate more accurate estimates of the value of cleaner air in China.

3.123 The monetized local environmental benefits were then added to the economic cash flows of the five renewable energy projects in order to see how their EIRRs would change. Table 3.14 presents the results for the four renewable energy power generation projects. The range of EIRRs with local environmental benefits correspond to the low and high externality values. Including these environmental benefits can have a significant impact on the economic performance of renewable energy projects. Adding low-valued local environmental benefits to the cashflow of the Inner Mongolia wind project raises its EIRR to 12 percent from 10.5 percent.

TABLE 3.14: RENEWABLE ENERGY PROJECT EIRRS WITH AND WITHOUT MONETIZED LOCAL ENVIRONMENTAL BENEFITS

Project	EIRR (%)	
	Excluding Local Environmental Benefits	Including Local Environmental Benefits /a
Wind-Inner Mongolia	10.5	12.0 - 13.4
Wind-Guangdong	5.4	5.9 - 6.2
Bagasse-Guangxi	32.9	33.8 - 34.5
Biogas-Beijing	18.3	18.4 - 18.6

/a The range corresponds to low and high values for avoided air emissions.

Source: Study team estimates.

Incremental Cost of Global Environmental Benefits

3.124 Renewable energy projects generate global environmental benefits by avoiding greenhouse gas emissions. Table 3.15 presents information on estimated carbon emission reductions for the five renewable energy case study projects.

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[24] Applying US data to China is problematic due to differences in background levels of pollution, morbidity and mortality and in the health effects of incremental air pollution. However, in the absence of China-specific comprehensive health-impact data, such an application is unavoidable.

TABLE 3.15: CARBON EMISSION REDUCTIONS FROM RENEWABLE ENERGY

Project	Annual Production (GWh/yr)	Lifetime Carbon Emission Reduction (tons)
Wind-Inner Mongolia	335	1,604,000
Wind-Guangdong	33	181,000
Bagasse-Guangxi	31	211,000
Biogas-Beijing	1	27,000
PV-Solar Home Systems	n/a	n/a

Source: Study team estimates.

4. INSTITUTIONAL AND POLICY ANALYSIS

4.1 China's economy is in transition from central planning to a socialist market economy. GOC's institutional and policy arrangements for renewable energy development need to be examined carefully to determine their suitability for an evolving socialist market economy. Experience in other countries illustrates the options available for market-oriented approaches to accelerating renewable energy development, and their results both positive and negative.

A. EXPERIENCE IN OTHER COUNTRIES

4.2 India, the United States and the United Kingdom have all made serious efforts to develop renewable energy, using government policies and financial incentives to spur market development.

4.3 **India.** The Government of India (GOI) supports renewable energy development as a means of alleviating energy problems, including: (a) an 83 percent increase in power demand between 1995 and 2000; (b) an increasing share of coal in meeting this demand; (c) difficulties in exploiting large hydro resources; and (d) uneven distribution of commercial energy. From 1973 to 1992, government programs focused on research and demonstration. They were based on heavy subsidies, rather than cost recovery. Some technologies were promoted before reaching technical readiness, or without adequate maintenance, and were perceived as unreliable.

4.4 In 1992, GOI shifted from supply-driven to market-driven programs based on commercialization, fiscal incentives, and reliance on the private sector. The Department of Nonconventional Energy Sources (DNES) was upgraded to a Ministry (MNES), and its role changed to one of facilitating private sector investment. Goals for development of power-related renewable energy systems during the Eighth Five-Year Plan (1992-97) were increased from 600 MW to 2,000 MW. The longer-term goal is to install 16,000 to 27,000 MW by 2015, accounting for 8 to 12 percent of power generating capacity.[25]

4.5 To increase financing for renewable energy, GOI incorporated the Indian Renewable Energy Development Agency Limited (IREDA) in 1987. IREDA offers financing to manufacturers and for renewable energy project developers. Terms and conditions vary by technology, approaching conventional terms.[26] In addition to providing loans, IREDA assists developers in project preparation, and assists states to prepare

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[25] See *IREDA News*, Vol. 6, No. 4, 1995, pp. 5-12.

[26] Interest rates of 2.5 to 15.5 percent, moratorium up to 3 years, and term up to 10 years.

project pipelines. IREDA has obtained funds from GOI, by issuing bonds, and from bilateral and multilateral donors. It has received a credit line from the World Bank of $195 million,[27] and is arranging an Asian Development Bank (ADB) credit line of $150 million. Other contributors to IREDA include DANIDA, the Swiss Development Corporation, and the Government of the Netherlands.

4.6 GOI also implemented fiscal incentives to encourage private-sector renewable energy investment. As of August 1994, incentives included:

- 100 percent depreciation in Year 1 of most renewable energy technology equipment (except small hydro systems);
- full exemption from excise duties and general sales tax in most states; and
- partial or full exemption from custom duties (major wind turbine components and Stirling engines are fully exempt).

4.7 Also, MNES has made it mandatory that states implement the following policies before receiving IREDA credit for grid-connected projects:

- power wheeling policy, permitting the power producer to withdraw electricity provided to the grid at any location for the developer's own use (2 percent wheeling fee);
- power "banking" policy, enabling the power producer to "bank" power with the grid for at least eight months per year;
- "floor level" buy-back rates and third-party sales of electricity;
- all financial and fiscal incentives available to other new industries;
- long-term lease of government land for establishing windfarms; and
- stable transmission and grid facilities at windfarm development sites.

4.8 These approaches, implemented since 1992, have succeeded in accelerating development, albeit at significant public cost. Grid-connected windfarms are the strongest example of success. In late 1992, there were 30 MW of installed capacity and two joint-venture manufacturers of wind turbines, with local content averaging 20 percent. Three years later, there are 560 MW installed and 22 joint ventures with local content as high as 70 percent. State-of-the-art 500 and 600 MW turbines are being introduced, while installed costs have been reduced by 40 percent to $1,100/kW. While IREDA interest rates for windfarms are nearing commercial terms, most windfarms have been financed

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[27] For the India Renewable Resource Development Project, to install 100 MW of small hydro, 85 MW of windfarms and 2.5 MW of solar PV.

from completely commercial sources. A significant problem with windfarm development is that development of transmission and distribution lines has not kept pace with windfarms at prime sites. GOI is considering scaling back accelerated depreciation for windfarms, in recognition of their increasing financial viability.

4.9 **United States.** During the 1970s, the United States faced an unprecedented crisis, because of sudden increases in oil import prices. This gave impetus to US policies for renewable energy development. The US government enacted the Public Utility Regulatory Policy Act (PURPA) of 1978, requiring utilities to purchase power from nonutility, renewable-energy or cogeneration power producers with capacities less than 80 MW. Responsibility for implementing PURPA, including determining the avoided costs at which the utility purchased electricity, was delegated to state authorities. As a result, states adopted varying implementation policies.

4.10 The most noteworthy development has been in California, which has rich wind, solar, biomass and geothermal resources. In 1979, there were 5 MW of private renewable capacity connected to the grid; today there are over 6,000 MW. California's success is attributed in part to standard power purchase agreements that:

- included both capacity and energy payments in the power purchase price, based on forecast prices for natural gas, the conventional alternative;
- presented fixed (i.e., predictable) energy payments for the first 10 years;
- offered a menu of payment options (with the same NPV) to permit revenue to be tailored to project needs; and
- reduced transaction costs.

4.11 These policies provided developers with the long-term price certainty required to obtain financing for capital-intensive projects. However, an oversupply of capacity developed and California ceased to offer the standard power agreements in 1984. At the same time, natural gas prices fell and the utilities' avoided costs fell dramatically. As a result, development of new renewable energy facilities slowed dramatically.

4.12 Because of the fall in avoided costs, PURPA was no longer effective in encouraging private-sector investment in renewable energy. Therefore, in 1992, the US government offered three incentives, as part of the Energy Policy Act (EPAct):

- Independent power producers receive a 10 percent federal income tax credit based on the cost of installed capital equipment for solar and geothermal power projects.
- Developers (investor-owned utilities and independent power producers) of biomass projects using energy crops and/or wind projects receive a

$0.015/kWh federal tax credit on power production during the first 10 years of the project. Projects must be installed by 1999.

- State and municipally owned utilities, which are exempt from federal income taxes, receive a $0.015/kWh federal payment, for wind and/or "closed loop" biomass projects.

4.13 These provisions have encouraged some investment in renewable energy facilities. However, because of low avoided costs for alternatives and limited demand growth, renewable energy is developing at a slower pace than in the 1970s and 1980s. This slow pace reflects the fact that the United States is in a different situation than India or China. Power demand is stagnant, and natural gas from North American sources offers a cheap, secure and relatively environmentally benign source of new power. However, development of nearly commercial sources such as wind continues, with current costs in the $0.045/kWh to $0.07/kWh range. PV development also continues, aiming at niche markets, but resulting in rapid and continual cost reductions.

4.14 **United Kingdom.** The United Kingdom is in a similar situation to the United States, with slow growth in power demand and an abundance of secure natural gas. However, its government has set a goal of working toward 1,500 MW of grid-connected renewable energy by 2000, in order to (a) ensure a diverse, secure, and sustainable energy supply; (b) reduce environmental impacts; and (c) encourage an internationally competitive renewable energy industry. To support its development goals, the United Kingdom extended the provisions of the Nonfossil Fuel Obligation (NFFO) of the 1989 Electricity Act beyond nuclear power to include renewable energy sources.[28]

4.15 Under the NFFO, all licensed electricity suppliers are charged a tax on revenue from the sale of electricity generated using fossil fuels. For 1994/95, the levy was set at 10 percent and resulted in the collection of over $1.8 billion. Revenues are used to "buy down" the purchase price of electricity generated from nuclear power and renewable energy.[29] Taxes are used to pay for the portion of the price of electricity from these sources, which exceeds the price that distribution companies pay for electricity from the grid (i.e., the power pool price, excluding transmission charges).

4.16 The NFFO has created a marketplace for renewable energy for power. To date, three NFFO Orders have been issued for renewable energy projects; a fourth Order is currently under consideration. Each Order provides an estimate of the total generating capacity to be procured, by technology. Projects are selected via competitive bidding. Bids are reviewed on the basis of development potential, and acceptable bids are prioritized by power purchase bid price. Contracts are awarded to those developers with

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[28] Only England and Wales are subject to the NFFO, although similar arrangements have been instituted for Scotland and Northern Ireland.

[29] In 1994/95, 8 percent of the collected tax, approximately $145 million, was used to purchase electricity from renewable energy resources

the lowest-cost projects until the required capacity is met. Contracts for over 1,250 MW of renewable energy generating capacity have been signed, including approximately 37 MW from small hydro, 166 MW from landfill gas, 263 MW from wind, 655 MW from municipal and industrial waste, and 104 MW from agricultural and forestry waste. However, it is expected that less than 800 MW of the 1,250 MW currently committed will be actually constructed, because of difficulties in obtaining local planning permission.

4.17 In establishing the NFFO process, the Government of the United Kingdom has maintained flexibility. This has allowed NFFO Orders to respond to the concerns of all parties. For example, to reduce bid prices, the third NFFO Order offered 15-year power purchase contracts, rather than the 8- and 6-year contracts offered earlier. Flexibility also allows Orders to be adjusted for changes in the status of renewable energy technologies. For example, the cost of power from sewage gas plants has declined to the point where the technology is commercially competitive with power pool alternatives, and excluded from the NFFO process. Virtually all sewage plants now generate their own power and many sell to the grid.

4.18 In addition to creating renewable energy investment of approximately $3 billion for the 1,500 MW planned for 2000, the NFFO orders have resulted in a decline in costs, due in part to developers moving along a learning curve. While not strictly comparable because the basis for bid prices have varied, the price of the most expensive contracted wind projects fell from $0.15/kWh in NFFO-1 to $0.063/kWh in NFFO-3, while the lowest-cost wind project in NFFO-3 was $0.056.

4.19 **Analysis of International Institutional Arrangements and Incentives**. While the approach taken in the three countries is different, there are common elements. All three examples show government support for development of an effective market for power from renewable energy. Central government leadership was critical, to define objectives and to put in place supporting policies, programs and financial incentives.

4.20 In the United States and the United Kingdom, minimal changes were needed to the regulatory and institutional framework for small power that was already in place. However, both governments mandated that power produced from small renewable power facilities must be purchased by the grid. Transaction costs were minimized, with standardized power purchase agreements. Fixed prices, with predetermined escalation clauses and hence predictable payments, are a feature of power purchase contracts in both countries, to aid developers in obtaining financing. In addition, financial incentives were offered, through higher-than-conventional prices in the United Kingdom and tax incentives in the United States.

4.21 In India, GOI was faced with a need to develop an institutional framework specifically for small power from renewable energy. The financial difficulties of many utilities meant that private power production for sale to the grid was unattractive. Therefore, GOI required state governments to institute wheeling and banking arrangements, so that power from renewable facilities could be banked and traded for power from the grid, under advantageous conditions. The result is that most project developers are industrial corporations, producing power for their own use or for sale to third parties (not utilities.) GOI created IREDA to offer concessional financing during an initial phase.

4.22 Each of the above countries implemented financial incentives to support an initial phase of removing barriers and reducing high implementation costs due to low market volumes. Proponents argued that the incentives were justified by long-term environmental and economic benefits expected from the development of a commercial renewable energy industry. These programs have helped to substantially reduce unit costs. Sometimes, governments also provided support such as resource assessment and assistance in project preparation.

B. EXISTING INSTITUTIONAL FRAMEWORK FOR RENEWABLE ENERGY FOR POWER IN CHINA

4.23 **Overall Planning and Coordination**. Three commissions guide the development of renewable energy in China: SPC, SETC and SSTC. SPC is in charge of planning and budget approval for large infrastructure projects. SPC also approves financing and foreign exchange requirements for large renewable energy projects. Renewable energy is handled by the New Energy Division under the Department of Transportation and Energy. SETC directs and coordinates economic operations, enterprise restructuring and retrofitting of industries. The Renewable Energy Division is under the Department of Energy Conservation and Comprehensive Utilization.

4.24 SSTC is in charge of planning and program administration of scientific research and development (R&D) projects, as well as technology transfer, including acquisition of foreign technology. In principle, SPC oversees large infrastructure projects, while SETC oversees upgrading of existing industries and SSTC oversees R&D. However, the New Energy Division of SPC, the Renewable Energy Division of SETC and the New Energy Division of SSTC sometimes overlap and operate competitively.

4.25 **Grid-Connected Power Development.** MOEP has been a focal point for development of grid-connected renewables, under the three commissions. However, China's power sector is undergoing reform to transform state power enterprises into autonomous corporations, responding to market signals. MOEP will be transformed into the National Electricity Power Company (NEPC) in 1996. Planning, policy, and regulatory functions are to be separated from administrative functions. A new Electricity Law was passed in December 1995, and regulations to be prepared under this law are expected to make significant changes.[30] The next step is expected to be the establishment of an independent national regulatory entity, which will consolidate regulatory functions dispersed among several ministries and commissions that now make tariff and other decisions under laws and State Council decrees, without obtaining the concurrence of

[30] The World Bank is providing technical assistance under the Institution Development Fund (IDF) project on "Legal and Regulatory Reform for China's Power Sector."

other government bodies. These reforms raise large issues about ownership of assets and future division of responsibility. Power sector reform is expected to take several years and be implemented in several steps.

4.26 The Electricity Law encourages development of renewables for both grid-connected and off-grid use. During the next three to five years, the transition arrangement could result in the consolidation of the regulatory functions with SPC/SETC and their provincial networks. This should facilitate continuation of the commissions' efforts to promote renewable energy development. However, the nature of that promotion will change to facilitating public and private investment in manufacturing of renewable energy technologies and installation of renewable power facilities.

4.27 **Off-Grid Power Development.** The existing arrangements for promoting rural energy technologies provide a basis for commercializing off-grid renewable technologies. The key implementing agencies are the Ministry of Agriculture (MOA) and MOWR. The Department of Environmental Protection and Energy of MOA supports a network of local rural energy offices in over 1,800 of the 2,200 counties in China. These offices have successfully promoted efficient biomass stoves and solar water heaters. For power generation, they are promoting wind generators and SHS.

4.28 An Integrated Rural Energy Development Program (IREDP) was initiated during the Seventh Five-Year Plan. In the Eighth Five-Year Plan, this program was extended to 141 counties (the Hundred-County Program). The total estimated program expenditure through 1995 was Y 10 billion. SPC is the lead organization and MOA's Department of Environmental Protection and Energy is the main administrative agency for the IREDP.[31] In many provinces, the New Energy Offices (associated with SSTC) have extensive programs in off-grid renewable energy utilization. For example, the New Energy Division in Inner Mongolia has promoted small wind generators, with 140,000 units in service.

4.29 MOWR's Department of Rural Hydropower is in charge of the small hydropower development program in rural areas. In China, some 800 counties are connected to isolated local grids mainly based on small hydro. MOWR has a provincial bureau and a network of county-level bureaus to develop the isolated hydro-based local grids. Small hydro stations are operated by county or village organizations and are autonomous with respect to accounting and setting tariffs.

4.30 In addition to MOA, MOWR and SSTC, the Office of Poverty Alleviation and Development of the State Council provides funds for renewable energy projects in impoverished areas. For example, this office has supported MOA on the Hundred-County Program and the use of photovoltaics in western China, particularly in Gansu and Qinghai.

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[31] SSTC, SETC, MOEP, MOWR, Ministry of Finance (MOF), and Ministry of Forestry (MOFO) all participate in this program

4.31 **Institutional Requirements.** GOC needs to strongly support renewable energy development, by increasing awareness of the technologies among government and energy company officials, and by better integrating renewable energy development into the nation's overall energy development program. Cooperation among the three commissions charged with this renewable energy development needs to be strengthened, as well as the capacity of each commission to play its role, especially SETC in leading commercialization efforts.

C. EXISTING POLICIES FOR RENEWABLE ENERGY DEVELOPMENT IN CHINA

4.32 **Existing Policy Framework.** While policies are still being developed, the 1995 GOC Renewable Energy Development Program Statement outlines five major policy objectives:

(a) To bring the development of renewable energy into the general plan of economic development and government budgets, as well as increasing the guidance from government and local authorities for this development.

(b) To formulate government policies favorable to renewables. Since most renewable energy technologies are under development, the scale of production is small, costs are high and their use is not yet financially viable. Therefore, renewable energy facilities are to be given government support, including:

- increased investment and financing for research and development;
- expanded credit including long-term, low-interest loans.
- exemption from taxes, provision of price subsidies and incentives.

(c) To intensify scientific research and technology development programs for 1996-2010 and work out the details of the Ninth Five-Year Plan.

(d) To strengthen the industrial base for manufacturing and support services for renewable energy development, including support through favorable treatment with respect to investment, price, and taxation. This should result in an increase in product quality, and a decrease in product costs.

(e) To bring about increased international cooperation, introducing advanced technologies and financing from abroad.

4.33 The three commissions are in charge of developing a set of policies to support development of renewable energy for power. The key issue is how to mobilize resources to move renewable energy technologies to the commercial stage. GOC has not made any specific budget allocations to support the New and Renewable Energy Development Program, as yet. Obtaining capital from nonstate sources is a great challenge in China because the economy is in transition, growing fast, and competing demands for long-term capital are great.

4.34 **Policy Constraints for Grid-Connected Applications.** Issues include lack of familiarity with power purchase agreements, lengthy and complex approval processes, limited access to long-term credit, inadequate financial incentives and lack of consideration of environmental benefits.

4.35 Currently, Chinese utilities have limited experience with **power purchase agreements**. This makes transaction costs of negotiating individual contracts high in relation to the small size of renewable energy projects. While few IPP projects have been approved, prospects are expected to improve with the passing of a BOT law later this year.

4.36 Currently, investments require a **lengthy approval process,** involving all concerned agencies, at five stages. Projects above 25 MW or Y 200 million require approval by central authorities, including SPC, SETC and MOEP. In addition, joint-venture projects and those requiring foreign exchange must be approved by the Ministry of Foreign Trade and Economic Cooperation and the Import and Export Controlling Corporation. If the project is over Y 500 million, or over Y 200 million and requires foreign exchange, it needs State Council approval. The process can be lengthy. It reportedly took three years for the Shajiao B coal-fired project in Guangdong to obtain all approvals.[32]

4.37 **Lack of access to credit** for renewable energy projects is an important issue in China, because the commercial banking system is not fully developed, and long-term credit is in short supply. China is still in transition from a centrally planned mode where investment was controlled and directed by the central government authorities. Continuing from this past, low-interest or no-interest loans have been made available from various government agencies for demonstration-scale renewable energy projects. An example is SETC's fund of Y 120 million for low-interest loans to renewable energy manufacturing and demonstration projects. With respect to foreign financing, low-interest and no-interest loans have been obtained from bilateral sources for purchase of renewable energy equipment. However, the amounts are too small to support commercial-scale development efforts.

4.38 MOEP has issued guidelines for **favorable power purchase prices**, as a financial incentive for grid-connected windfarms. The governments of Inner Mongolia, Xinjiang and Guangdong have adopted the guidelines and set such prices, varying from Y 0.63 to Y 0.70/kWh. However, since these prices do not escalate, the levelized power price in constant 1995 yuan is estimated at Y 0.43 to Y 0.47, after correcting for inflation. While

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[32] See "Approving Power Investments" in the *China Business Review*, November-December, 1993, p. 36.

these prices are 30 percent higher than the estimated economic avoided energy costs, they do not provide a sufficient rate of return above costs and taxes to attract investment.

4.39 **Environmental benefits** are generally not considered in setting power purchase prices. In some other countries, these benefits are evaluated as part of project selection and through retroactive standards for pollution abatement equipment. More work is needed on assessing the environmental damages of conventional power technologies and the benefits of renewable energy, and incorporating these benefits into project evaluation and selection criteria.

4.40 **Policy Constraints for Off-Grid Applications.** The commercialization of off-grid technologies requires: (a) credit for both suppliers and consumers of off-grid systems; (b) servicing and marketing infrastructure; and (c) product certification and quality control.

4.41 Current access to commercial credit is limited (see para. 4.37). Off-grid system suppliers need credit to expand their markets, to develop sales and service facilities and to improve quality and lower costs of products.

4.42 Limited **access to credit by consumers** is a barrier to increasing both the average system size and the total market potential. Off-grid renewable power systems have a high initial cost, since the majority of the life-cycle cost is in the purchase price. Without access to credit to spread these costs over time, the market is limited to those who can afford cash purchase. Only the smaller-size systems can find a ready market under these conditions. These systems have been promoted in China by a subsidy—for example, a Y 300 subsidy on a 20 Wp SHS that costs about Y 1,700. As incomes rise, the small systems will not meet the demand for color televisions, fans, and productive uses. However, banks and cooperative lending associations in China, as elsewhere, do not lend for off-grid power systems. While consumer credit is limited, there are models for directed consumer credit in China (see Chapter 3, Section D).

4.43 For off-grid systems, there is a need for GOC to establish **product standards**, testing facilities for **certification and quality control**. Because small off-grid systems are often operated by households, they must require little maintenance and be reliable. Currently, some small PV systems are not designed for long-term reliable service. Failures will damage the market for SHS. More than one qualified supplier is needed to ensure competition.

4.44 **Policy Requirements.** While GOC is putting in place a number of policies to encourage renewable energy, these policies are generally not market-based and have not been developed within a comprehensive framework. GOC urgently needs to utilize the experience of other countries to put together a regulatory and policy framework, financial incentives and other supporting institutional arrangements required to accelerate market-based development of renewable energy for power. On the regulatory side, GOC should develop a standard small power purchase agreement and tariffs, and a simplified approval process. As well, GOC needs to consider ways to increase the availability of credit for renewable energy and put in place product standards, certification and quality control measures.

4.45 Where necessary, GOC should consider modest financial incentives that are based on the following principles:

(a) the level of the financial incentive should be determined by the difference between current costs and expected long-run economic value of the power;

(b) the financial incentive should be available for a limited time and progress toward cost reduction monitored; and

(c) the mechanism used to deliver the incentive should not create distortions to the market, but should recognize the potential economic benefits of renewable sources of energy.

5. PRIORITIES FOR RENEWABLE ENERGY DEVELOPMENT FOR POWER IN CHINA

A. OVERVIEW

5.1 Examination of international experience indicates that GOC needs to take a larger-scale and market-based approach to renewable energy development. This joint study has begun the process of identifying the most promising technologies. In the next year, GOC urgently needs to set the institutional and policy framework; to develop appropriate financial incentives, where necessary; and to prepare and implement key investment and technical assistance activities.

5.2 Expanded support from multilateral and bilateral agencies will be important to implement many of the priority investment and technical assistance activities outlined below. International assistance is especially important in the following areas: (a) assistance in reviewing options for promotion policies and financial incentives to encourage investment in renewable energy facilities; (b) demonstration and transfer of advanced technology to China, to lower costs and improve technology performance; (c) assistance in developing institutional arrangements, e.g., in developing power purchase agreements for windfarms and biomass plants, and developing standards and certification procedures for equipment; and (d) provision of additional long-term capital from international public and private sources. Resources from the GEF can be used to promote and accelerate priority policies, investment and technical assistance projects for renewable energy development in China.

5.3 Priorities for GOC investment and technical assistance are outlined below and summarized in Table 5.1.

B. POLICY PRIORITIES

5.4 **Technical Assistance**. GOC needs to give the highest priority to support for technical assistance activities to develop appropriate policies in the following areas:

- strengthening the capacity of the three commissions to lead renewable energy development, and improving coordination among them;
- assist in making the New and Renewable Energy Development Program larger-scale and market-based;
- review options for developing a policy framework for investment in small renewable power facilities, considering the following needs:
    - standard small power purchase agreement, especially for wind and bagasse cogeneration;

- streamlined approval process;
- increased availability of credit to suppliers and purchasers of renewable energy technologies;
- product standards, certification and quality control;

- review options for developing carefully targeted financial incentives to stimulate market development, where necessary, based on the principles outlined at the end of Chapter 4;
- assist in developing an industrial strategy for key technologies such as solar PV; and
- valuing environmental benefits of renewable energy technologies, by estimating damage costs from local impacts of conventional technologies.

5.5 These activities need to be carried out jointly by responsible agencies from the central government and provincial governments. Workshops among government agencies, and with renewable energy development companies and financing agencies, would be useful to organize discussion and ensure ultimate acceptability of the proposed policies.

C. TECHNOLOGY DEVELOPMENT PRIORITIES

5.6 Technologies were assessed in Chapter 3 in terms of economic and financial viability, potential contribution to power supply in China, requirements for commercialization and environmental impact. Provided that certain policy and institutional constraints are resolved, the study indicates that three technologies are ready for efforts aimed at large-scale market development: grid-connected windfarms; solar PV, especially SHS; and bagasse cogeneration. Other technologies require technical support before commercial development, but have substantial potential in the long run (see Table 5.2 for a summary of results).

Grid-Connected Windfarms

5.7 Windpower has the highest resource potential of any of the technologies examined, at 250 GW. While the economically exploitable windpower potential is only a fraction of this, it is likely to be at least as significant as that of small hydro. Development of the best windfarm sites is close to economic viability, even when power is valued only at the avoided energy cost. If local environmental benefits are added, windfarms on sites like Huitingxile are economically viable today. However, financial rates of return are unattractive due to the effect of duties and taxes at the upfront stage of this capital-intensive investment. Reducing current costs by 20 percent would make windfarm development both economically and financially viable. With large-scale windfarm development, a cost reduction of this magnitude is achievable through increasing local content and incorporating technology advances, as demonstrated in India. GOC needs to support the following activities as part of a windfarm development program.

TABLE 5.1: PRIORITIES FOR INVESTMENT AND TECHNICAL ASSISTANCE

Areas for Development	Investments	Technical and Other Assistance	Expected Results
Policy	n.a.	• Strengthen three commissions and improve coordination • Make Renewable Energy Development Program larger-scale, more market-based • Develop policies to encourage small power production from renewable energy • Review and restructure financial incentives • Develop industrial strategy for key technologies • Analyze and value environmental benefits from renewable energy for power	Develop institutional and policy framework to encourage large-scale public and private investment
Windfarms	• Commercial-scale windfarms at Huitingxile or similar sites (~1,000 MW) • Large, 500+kW wind turbine manufacture	• Wind resource and performance monitoring of existing windfarm sites and grid interconnection • Wind resource assessment at potential and new sites • Capacity building of power utility staff	Build portfolio of windfarm projects, reduce uncertainty, reduce costs, demonstrate commercial arrangements, reach financial viability.
Solar Home Systems	• 500,000 households off-grid electrification program • Expand silicon manufacture • Expand module and balance-of-system components manufacture • Expand systems assembly operations	• PV industry sector development strategy • SHS product development, business development and planning • Product certification and quality control • Training and support for sales and service network • Consumer education	Rationalize PV industry, increase market scale, lower costs and improve quality, develop commercial infrastructure, increase productivity of PV module industry
Bagasse Cogeneration	• 350 MW, 39 mill expansion project in Guangxi (funding required urgently to coincide with increased sugar processing capacity investments) • Cogeneration in other provinces	• Conduct feasibility and detailed design studies for sugar mills in Southern provinces • Prepare guidelines and designs for advanced cogeneration investments involving high temperature/pressure equipment • Develop a demonstration project • Develop PPA and investigate grid integration issues	Produce power on commercial basis and serve as model for standard procedures in future mills
Small Hydro	• Further investment, especially to improve efficiency and regulated capacity	• Automation, efficiency improvement, quality control, design improvement, economic evaluation	Increased effectiveness of existing program.
Geothermal Power	• Conduct feasibility study of 10 MW facility in Tengchong County, Yunnan • Subject to feasibility, production well and power plants at other sites	• Geoscientific investigations, exploratory well testing Rehai geothermal field and if warranted, feasibility study for development of Rehai field • Reassessment of geothermal potential, including both resource data and economic viability in western Yunnan and Tibet	Investment at Rehai and other sites depending on results of feasibility studies and resource assessments
Biogas for Power	• Biogas and power generation plants at large piggeries (>50,000 pigs) and other livestock operations	• Study of areas for technical improvements, environmental externalities and any incentive measures justified • Exchange of information on improving process efficiency, engine performance, develop low-cost materials	Reduce effluents from large agricultural operations
Solar thermal electric, wind and PV hybrids	• Include wind and PV hybrids in off-grid electrification program	• Develop/introduce advanced design techniques • Assist product development of hybrids • Examine potential for advanced wind-PV, PV diesel and other hybrids • Evaluate feasibility of parabolic trough technologies in regions other than Tibet with higher demand and availability of back-up fuel • Assess feasibility of coal-solar thermal parabolic trough designs • Pilot projects involving solar thermal dish Stirling and other advanced power generation technologies	Add to portfolio of off-grid and grid-connected technologies

TABLE 5.2: SUMMARY OF EVALUATION RESULTS

Project, Province	Installed Capacity (MW)	Financial Capital Cost (million yuan)	EIRR (%)	EIRR with Environmental Benefit (%)	FIRR (%)	Site Potential (MW)	National Exploitable Potential (MW)	Constraints to be Overcome
Windfarms, Huitingxile, Inner Mongolia	100-200	945-1,890 (today) 790-1,580 (2001)	10 (today) 15 (2001)	12-13 (today)	10 (today) 18 (2001)	1,000	n.a.	Lack of financing; technical, cost and contractual uncertainties, import duty, VAT
Solar Home Systems, Northwest and North-center	12 (500,000 households)	1,300	10	n.a.	10	n.a	n.a.	Affordability, lack of credit, product quality, product cost, market infrastructure and scale
Bagasse Cogeneration, Guangxi	350	2,200	33	34-36	20	350-450	700-900	Lack of financing, need for coordinated investment between sugar production expansion and power generation, technology transfer and technical assistance
Biogas for Power Plants, Beijing	0.3	0.4	18	19-20	5	4 (Beijing)	100	Lack of environmental standards, not financially viable except for largest operations, high transaction costs for small projects
Geothermal Plant Rehai, Yunnan	10	n.a.	n.a.	n.a.	n.a.	100	500	Insufficient data on resource, need assistance in resource assessment and feasibility studies

/a Incremental cost contribution needed to increase EIRR to 12 percent.

5.8 **Investment.** Given the large potential for grid-connected windpower and GOC's target of 1,000 MW installed by 2000, GOC investment assistance is needed to lay the foundation for a sustainable, commercially viable windpower industry in China. High priority investments are:

- immediate installation of commercial-scale windfarms (100 to 200 MW), at sites with large potential, such as Huitingxile, to demonstrate commercial viability, create a market for local manufacture, and resolve uncertainties; and

- future domestic manufacture of state-of-the-art, 500+ kW turbines, as the market develops, in order to lower costs.

5.9 Commercial-scale demonstration at a site such as Huitingxile is a high priority, because it could reduce uncertainty, lead to domestic manufacture, reduce costs and lead to the installation of up to 1,000 MW in a single site. Financial incentives are likely to be needed for a first phase of commercial development.

5.10 **Technical Assistance**. Technical assistance support that is important for windfarm development includes the following activities:

- wind resource assessment activities at potential sites, and investigation of additional sites;

- monitoring of wind resources and windfarm performance at existing pilot sites, including instrumentation of turbines and the grid interconnection;

- training of the staff of power utilities on windfarm technology and its interaction with the grid, e.g., analysis of LOLP on the grid, with and without windfarms, and estimation of capacity credit for windpower.

Solar PV/Solar Home Systems

5.11 The potential for solar home systems is small in terms of megawatts, but large in terms of meeting an essential need: the provision of electricity for the basic needs of remote area households. A 12 MW solar home systems project can cover 500,000 homes in five northwestern provinces, 40 percent of the unelectrified households in China today. In the areas considered, SHS are least-cost electricity supply sources. They improve living conditions by providing new service levels well above those from kerosene/butter lamps and dry-cell batteries. An SHS program of the size proposed would triple the size of the current PV market in China and have a major impact on accelerating development of the PV industry. It could assist in rationalizing the PV industry; increasing market scale; lowering costs; improving product quality; and, developing commercial infrastructure. Environmental impacts from reducing kerosene/butter use and dry-cell batteries are not large. However, the environmental impact of SHS development will come from its impact on reducing PV system costs overall, leading toward a larger market for PV systems in other applications, including grid-connected load support.

5.12 Again, SHS are near economic and financial viability, but may require GOC to provide financial incentives during an initial phase. With large-scale commercialization, it is estimated that costs can be reduced by 30 percent within five years, eliminating the need for financial incentives after that period. A large-scale SHS program requires: (a) market development activities; (b) improvement in module manufacturing and system assembly facilities; (c) product certification and quality control; and (d) development of the infrastructure for sales and service support.

5.13 **Investment**. The study indicates that GOC should give high priority to investment in the following:

- a large-scale solar home systems market development project, aiming to provide electricity to 500,000 households in five northwestern provinces of China (12 MW in five years, tripling the 1994 PV market). The project may include subsidies and/or credit to consumers during an initial period, and assistance to suppliers to improve their manufacturing/assembly operations, product quality, and to establish sales and service networks;

- installation of centralized PV stations and PV/wind hybrid stations in remote county towns, where cost-effective; and

- expansion of local silicon manufacturing, module and balance of system manufacturing, and system assembly operations, as part of an industrial strategy to increase PV industry efficiency and lower costs.

5.14 **Technical Assistance.** Priorities for GOC technical assistance are:

- development of a PV industry sector strategy, primarily for manufacturing but also for research and development;

- establishing product specifications and strengthening the capability of a national quality certification agency to test and qualify products;

- providing product and business development assistance to PV system suppliers;

- training and support for sales and service network; and

- market studies and consumer education programs.

Bagasse Cogeneration for Surplus Power

5.15 The economically exploitable bagasse cogeneration potential is estimated conservatively at 700 to 900 MW in China today. However, immediate action is needed to achieve this potential as sugar mills are expanding in several provinces to meet growing demand. If bagasse cogeneration systems to produce surplus power are added during mill expansion, they provide very attractive investment opportunities, on both an economic and financial basis, with an EIRR of 33 percent and an FIRR of 20 percent. Consideration of local environmental benefits raises the EIRR by 1 to 1.5 percent.

5.16 While the necessary operating practices are not in use in China, they can be transferred easily. The potential for surplus power is 350 to 450 MW in Guangxi alone. To obtain this potential, the sugar industry needs assistance from GOC in obtaining long-term debt financing and technical assistance to develop mill-specific design and operating plans.

5.17 **Investment.** The study indicates that GOC should give high priority to investment in bagasse cogeneration for surplus power production including:

- a major mill expansion program in Guangxi, to install cost-effective generating capacity to deliver surplus power to the grid, estimated at 350 to 450 MW; and
- investment in cogeneration in other provinces. The potential in other provinces in total is estimated to be equal to that of Guangxi.

5.18 **Technical Assistance.** Technical assistance priorities include the following:

- feasibility and detailed design studies for cogeneration systems in sugar mills;
- immediate demonstration of joint operation of sugar production and power export; and
- development of an appropriate power purchase agreement and investigation of grid integration issues.

Other Technologies

5.19 Biogas power projects are generally economic but are financially viable only at extremely large farms. The potential for cost reduction in biogas power systems is currently limited to engine efficiency improvement, which by itself is insufficient to raise the financial viability of the projects at average farm sizes. In addition, the total economic potential nationwide was found to be small (100 MW) in comparison with the other grid-connected options. For geothermal power, work is still needed to define the resources available nationally and in the prime areas in Yunnan and Tibet, in relation to potential power demand. Specifically, exploratory wells need to be drilled in Tengchong County, Yunnan, and the benefits and costs of a proposed 10 MW installation at the site investigated.

5.20 **Investment.** The following investments in other technologies are indicated to be priorities, although their potential for impact is more limited.

- Subject to feasibility work, investment in a geothermal facility in Tengchong County, Yunnan, and in other locations;

- biogas for power plants at large piggeries (more than 50,000 head) and other large livestock operations; and

- include small wind generators, wind/PV hybrids and centralized PV in off-grid electrification programs.

5.21 **Technical Assistance**. Technical assistance is needed for specific investigations related to the other technologies discussed in this report:

- assessing the feasibility of biomass for power generation from other captive wastes and fuelwood from plantations in areas such as Yunnan; and further reviewing technical and economic issues, and environmental externalities associated with large-scale biogas generation;

- investigating the potential for geothermal energy, including drilling of wells and prefeasibility work in Tengchong County, Yunnan; and investigation of economic potential from lower-temperature resources throughout Yunnan and Tibet;

- improving efficiency and quality of small hydropower equipment, design of facilities, economic evaluation methods and pricing;

- investigating potential for further commercial development of small wind generators, PV/wind hybrids and wind/diesel hybrids;

- studying possible incentives for biogas for power plants, and exchanging technical information with the international community, to improve process efficiencies, improve performance of biogas-powered engines, and develop new, lower-cost materials; and

- investigating potential applications in China of emerging commercial technologies, such as dish-Stirling and solar-thermal parabolic-trough power plants.

ANNEX 1: EXECUTIVE SUMMARY OF THE AVOIDED COST STUDY

Introduction

1. The Government of China (GOC) and the World Bank jointly initiated the China Power-Related Renewable Energy Development Study to identify priorities and strategies for China's power-related renewable energy development.

2. A primary task of the study is an assessment of the economic viability of renewable energy technologies compared with conventional alternatives. Case studies of six power-related technology applications are being prepared, four of which are located in proximity to regional/provincial electricity grids:

(a) **Windfarms**, in Inner Mongolia (North China Power Network—NCPN) and on Nan'ao Island (Guangdong Provincial Grid—GDPG);

(b) Distributed building-interactive photovoltaic systems, in Beijing (NCPN) and in Guangzhou (GDPG);

(c) Biogas generation, near Beijing (NCPN); and

(d) Bagasse cogeneration in Guangxi (Guangxi Provincial Grid—GXPG).

3. The objective of this consultancy is to facilitate the estimation of economic benefits for these grid-connected renewable energy installations by calculating the economic value of electricity supply—the "avoided cost" of capacity and energy—on each of the three grids that would potentially purchase power from the case study projects.

The Economic Rationale for Avoided Costs

4. Economic theory states that prices set equal to marginal cost provide correct signals to the market—buyers and sellers—and result in a market equilibrium at a level and pattern of electricity supply that provides for the most efficient allocation of scarce resources.

5. The concept of "avoided cost" is closely linked to marginal cost. Avoided cost is the cost that a buyer—in this case, one of the regional/provincial power authorities under study—can offer for the purchase of energy or capacity. (It is the maximum value of the resources used to produce power and, therefore, the maximum amount that the grid should be willing to pay for power from alternative sources.) Avoided energy cost can be estimated as the value of one kWh displaced "at the margin" when a power purchase is made. Avoided capacity is the cost that a utility would have incurred to build capacity

that can be deferred as the result of a power purchase. Additionally, investment in network (transmission and distribution) capacity may be avoided if a power producer is located in close proximity to the load center that it serves.

6. Avoided costs are differentiated by season and by time of day. In this study, avoided costs of energy and generation capacity are calculated based on the generating units that are forecast to provide marginal energy and capacity to the grid in the future. Avoided network costs are defined as the incremental cost of a kW of peak-carrying capacity to the system. Avoided costs are forward-looking costs rather than historically embedded costs; therefore, they are based on long-term load forecasts and investment plans rather than the power system as it exists today.

Avoided Costs on the Three Study Grids

7. This analysis focuses on the main power grid in each study region. Estimated full avoided costs of capacity and energy on each of these main grids are summarized in Exhibit S-1 for delivery at very high voltage (220 kV and above), high voltage (35 to 110 kV) and medium voltage (6 to 10 kV). Costs vary by voltage level due to line losses and voltage-specific network investment requirements. Avoided energy costs have been aggregated into six separate rating periods, two seasons ("Dry" and "Wet") and three diurnal time blocks ("Peak," "Mid-Peak," and "Off-Peak") within each season. Differences are dictated by time variation in generation unit availability and system load.

Avoided Costs Recommended for Project Evaluation

8. Energy delivered by renewable energy producers should be valued at the full avoided of energy (Y/kWh) as reported in Exhibit S-1.

9. All grid-connected renewable projects should receive avoided capacity credits according to their contribution to system reliability. To approximate this contribution, the avoided capacity costs presented in Exhibit S-1 have been allocated to those times of the year when capacity is of greatest value to the system. Specifically, the full avoided cost of generation capacity has been allocated to seasonal/diurnal rating periods according to the risk of exposure to loss-of-load (i.e., estimated share of annual LOLP). Similarly, the full avoided network capacity cost has been allocated to periods of peak power flows. A renewable project is entitled to capacity benefits only for deliveries made during these time periods.

10. Further, avoided generation costs have been adjusted to reflect the availability of the proxy plant used in avoided cost calculations (i.e., a gas turbine with 87 percent annual availability). Thus, a renewable generator which is available 87 percent of the time would receive the full avoided cost of generation capacity.

Exhibit S-1: SUMMARY OF AVOIDED COSTS BY GRID

Delivery Voltage /a	Avoided capacity 1995 Yuan/ckW-mo			Avoided energy (1995 Yuan/kWh Dry season /b			Wet season		
	Generation	Network	Total	Peak	Mid-Peak	Off-Peak	Peak	Mid-Peak	Off-Peak
JJT Main Electric Power Grid									
VHV	54.01	0.00	54.01	0.3624		0.1454	0.3624		0.1454
HV	55.76	18.99	74.76	0.3742		0.1491	0.3742		0.1491
MV	57.16	27.58	84.74	0.3835		0.1520	0.3835		0.1520
Guangdong Main Electric Power Grid									
VHV	54.2	0.00	54.20	0.3596	0.2741	0.2402	0.3354	0.2694	0.2344
HV	56.25	17.86	74.11	0.3731	0.2818	0.2477	0.3480	0.2770	0.2417
MV	57.69	26.03	83.72	0.3827	0.2878	0.2530	0.3569	0.2828	0.2469
Guangxi Main Electric Power Grid									
VHV	53.98	0.00	53.98	0.3700	0.3023	0.2788	0.2767	0.2721	0.2716
HV	55.69	18.67	74.36	0.3817	0.3092	0.2863	0.2855	0.2785	0.2790
MV	57.01	27.39	84.40	0.3908	0.3154	0.2921	0.2922	0.2841	0.2846

/a Network defined as: VHV (500/220 kV), HV (110/35 kV and above), MV (10/6 kV), LV (<1 kV).
/b Rating periods of each grid:

	Peak	Mid-Peak	Off-Peak	Dry Season
JJT	07:00-22:59		23:00-06:59	all months weighted equally
Guangdong	18:00-23:59	07:00-17:59	0:00-06:59	November through March
Guangxi	18:00-23:59	07:00-17:59	0:00-06:59	November through April

11. Avoided capacity costs are credited per kWh delivered by rating period. This mechanism assures that the avoided cost for a renewable resource is allocated in proportion to its actual contribution to the system. It also permits use of a single avoided cost (Y/kWh) in each rating period to reflect the value of energy and capacity avoided by renewable generation delivered to the grid.

12. Avoided energy and capacity payments, expressed on a per kWh basis for each rating period, are summarized in Exhibit S-2. As discussed in Section 6.2, these avoided cost calculations do not incorporate the impact of probable future laws requiring environmental control equipment for coal plants. Exhibit 6.5 of the text reports avoided costs derived assuming an average capital investment of $250 per kW for these controls.

Exhibit S-2: AVOIDED COSTS FOR PROJECT EVALUATION

Delivery Voltage /a	Avoided Costs—Capacity and Energy (1995 Yuan/kWh): Dry season /b: Peak	Dry season /b: Mid-Peak	Dry season /b: Off-Peak	Wet season: Peak	Wet season: Mid-Peak	Wet season: Off-Peak	Average Yuan/kWh /c
JJT Main Electric Power Grid							
VHV	0.4899		0.1454	0.4899		0.1454	0.3751
HV	0.5449		0.1491	0.5449		0.1491	0.4130
MV	0.5752		0.1520	0.5752		0.1520	0.4341
Guangdong Main Electric Power Grid							
VHV	0.6053	0.3635	0.2402	0.5109	0.3332	0.2344	0.3651
HV	0.7261	0.3746	0.2477	0.6281	0.3432	0.2417	0.4018
MV	0.7869	0.3829	0.2530	0.6864	0.3508	0.2469	0.4217
Guangxi Main Electric Power Grid							
VHV	0.6760	0.4135	0.2788	0.3787	0.3092	0.2716	0.3777
HV	0.7997	0.4240	0.2863	0.4930	0.3168	0.2790	0.4138
MV	0.8640	0.4329	0.2921	0.5500	0.3233	0.2846	0.4342

Delivery Voltage /a	Avoided energy costs (1995 yuan/kWh): Dry season /b: Peak	Dry season /b: Mid-Peak	Dry season /b: Off-Peak	Wet season: Peak	Wet season: Mid-Peak	Wet season: Off-Peak
JJT Main Electric Power Grid						
VHV	0.3624		0.1454	0.3624		0.1454
HV	0.3742		0.1491	0.3742		0.1491
MV	0.3835		0.1520	0.3835		0.1520
Guangdong Main Electric Power Grid						
VHV	0.3596	0.2741	0.2402	0.3354	0.2694	0.2344
HV	0.3731	0.2818	0.2477	0.3480	0.2770	0.2417
MV	0.3827	0.2878	0.2530	0.3569	0.2828	0.2469
Guangxi Main Electric Power Grid						
VHV	0.3700	0.3023	0.2788	0.2767	0.2721	0.2716
HV	0.3817	0.3092	0.2863	0.2855	0.2785	0.2790
MV	0.3908	0.3154	0.2921	0.2922	0.2841	0.2846

/a Network defined as: VHV (500/220 kV), HV (110/35 kV and above), MV (10/6 kV), LV (<1 kV).
/b Rating periods of each grid:

	Peak	Mid-Peak	Off-Peak	Dry Season
JJT	07:00-22:59		23:00-06:59	all months weighted equally
Guangdong	18:00-23:59	07:00-17:59	0:00-06:59	November through March
Guangxi	18:00-23:59	07:00-17:59	0:00-06:59	November through April

/c Average of avoided capacity and energy costs estimated for comparison purposes only assuming a flat load profile at the availability of the gas turbine.

ANNEX 2: ANALYSIS OF ENVIRONMENTAL BENEFITS FROM POWER-RELATED RENEWABLE ENERGY TECHNOLOGIES

AVOIDED ENVIRONMENTAL IMPACTS

1. Renewable energy projects in China will generate significant environmental benefits by offsetting power generation from existing coal- and oil-fired power plants or by deferring the need for new power plants or hydroelectric dams or, in the case of photovoltaic solar home systems, by offsetting indoor kerosene combustion and battery use. This annex identifies the range of environmental impacts of thermal power generation, kerosene combustion and battery use that are avoided by the renewable energy case study projects analyzed in this report. This annex also discusses how the environmental benefits of renewable energy have been analyzed in other jurisdictions and how this type of analysis might be incorporated into the economic analysis of renewable energy in China. It calculates the environmental benefits of the five renewable energy case study projects using proxy externality values, in order to determine their relative magnitude. Finally, this annex presents results on the incremental cost of carbon emission reductions associated with the renewable energy case study projects.

Local Impacts of Thermal Power Generation

2. Since renewable energy projects in China offset mostly coal- and oil-fired generation, as opposed to hydroelectric or nuclear generation, this annex focuses on the environmental impacts of fossil fuel resources.

3. Local environmental impacts of thermal power generation can be divided among three pathways: air, water and land.

4. **Air**. The most pervasive local environmental impact of thermal power generation is air pollution. Coal- and oil-fired plants emit particulates, sulfur dioxide, nitrogen oxides, toxics and other compounds that are hazardous to human health and local ecosystems. Particulates aggravate preexisting heart and respiratory illnesses and, over the long term, damage lung tissues, which contributes to chronic respiratory disease, cancer and premature illness and death. Sulfur dioxide causes constriction of the airways in asthmatics and other sensitive individuals and, over the long term, leads to symptoms of chronic bronchitis. Particulates and sulfur dioxide also react together to form more hazardous acid sulfate particles, which are inhaled deeper into the lungs where they cause damage. Nitrogen oxides damage the cells lining the lungs and, over the long term, cause changes in lung structure and function resembling emphysema and chronic bronchitis. Both sulfur dioxide and nitrogen oxides convert into acids in the atmosphere and lead to acid rain and dry deposition, which harms plants everywhere and animals in affected water

bodies. Finally, toxics emitted by coal- and oil-fired plants cause cancer and other human illnesses.

5. Data from the Chinese Ministry of Public Health indicate that chronic obstructive pulmonary disease, which has been linked to exposure to fine suspended particulates and sulfur dioxide, was the leading cause of death in 1988, responsible for 26 percent of all deaths.[1] While some of these deaths can be partly blamed on smoking and other behavioral factors, air pollution has a major impact on human health in China, making the incremental contributions of thermal power plants that much more important. The Government of China made the improvement of air quality one of its major objectives in *China's Agenda 21*, its 1994 white paper on environment and development.

6. While new, large coal-fired power plants in China are being equipped with pollution control technology, residual emissions still harm people and plant life nearby. This is especially true of particulates. Many cities in China suffer from levels of ambient particulate concentrations that far exceed safe standards issued by the World Health Organization (WHO). Particulate emissions from thermal power plants near populated areas exacerbate this situation. Thermal power generation also leads to air pollution from coal mining, transportation and handling.

7. The following table provides estimates of local air emissions from power plants that are offset by the renewable energy case study projects analyzed in this report.[2] The estimates for the first four projects are based on analysis that matches the level and timing of renewable energy power generation with avoided generation from marginal coal- and oil-fired plants with pollution control equipment in each of the three regions of China.

Table 1: AVOIDED LOCAL AIR EMISSIONS
(tons per year)

Project	Size	Total Suspended Particulates	Sulfur Dioxide	Nitrogen Oxides	Toxics
Wind - Inner Mongolia	100 MW	420	1,240	670	10
Wind - Guangdong	11 MW	120	210	60	1
Bagasse - Guangxi	9 MW	130	240	70	2
Biogas - Beijing	1 MW	0	2	2	0
PV Solar Home Systems	400,000	n/a /a	90	n/a	n/a

/a TSP emissions from kerosene lamps are not available but would be high.

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[1] World Bank, 1992, *China Environmental Strategy Paper*, p. x.

[2] The figures in the table exclude air emissions from coal mining, transportation and handling.

8. **Water**. Thermal power generation causes thermal and chemical water pollution. Thermal water pollution refers to the discharge of warm water to surrounding water bodies from a power plant's cooling system. This warm water can disrupt local ecosystems that are accustomed to a cooler water environment. Chemical water pollution refers to residual chlorine and other chemicals that are discharged in the wastewater from plants with once-through cooling systems. Chlorine is toxic to plants and animals. Oil-fired generation also creates the risk of oil spills during the transportation and unloading of oil barges.

9. The biogas case study project would further reduce water pollution by decreasing the release of organic material to water bodies in the vicinity of the pig farm. Without the biogas plant, the pig farm would release biodegradable organic compounds directly to the environment where they deplete natural oxygen levels in water bodies and result in septic conditions. The biogas project would reduce releases of these compounds by 90 percent through anaerobic digestion.

10. **Land**. Thermal power plants generate bottom ash that requires disposal in landfill sites or construction material. Since this ash contains heavy metals and other toxics, it creates the risk of local pollution if these compounds leach into surrounding groundwater or local water bodies.

Local Impacts of Indoor Kerosene Combustion and Battery Use

11. As a petroleum product, kerosene combustion emits pollutants like those identified above. However, since kerosene is burned indoors for the purposes of lighting in many rural Chinese homes, its combustion leads to levels of ambient air pollution that are many times higher than those found outdoors in polluted cities. It is therefore a greater concern for human health than the combustion of fossil fuels in thermal power plants.

12. Dry-cell batteries are used to power radios and other small appliances. Since the batteries contain small amounts of heavy metals such as mercury, cadmium, lead and zinc, these toxics can leach into the ground after disposal.

Global Impacts

13. The chief global environmental impact of thermal power generation and kerosene combustion in China is the emission of carbon dioxide and its associated impacts on global climate change. Renewable energy projects reduce carbon dioxide emissions by offsetting thermal power generation and kerosene combustion. The following table provides estimates avoided carbon emissions. Again, the estimates for the first four projects are based on analysis that matches the level and timing of renewable energy power generation with avoided generation of marginal resources in each of the three regions of China.

Table 2: AVOIDED ELECTRICITY GENERATION AND CARBON EMISSIONS

Project	Size	Avoided Coal Generation (GWh/yr)	Avoided Oil Generation (GWh/yr)	Avoided Carbon Emissions (tons/yr)
Wind - Inner Mongolia	100 MW	230	105	80,200
Wind - Guangdong	11 MW	33	0	9,000
Bagasse - Guangxi	9 MW	31	0	10,600
Biogas - Beijing	1 MW	1	0	1,400
PV Solar Home Systems	400,000	n/a	n/a	8,200

14. The avoided carbon emissions due to the biogas project combines three different effects. Incremental carbon emissions from methane-fired power generation offset carbon emissions from coal- and oil-fired power generation and methane emissions from uncontrolled decomposition of pig waste. As shown in Table 3, the avoided methane emissions dominate the three effects and generate a large greenhouse gas benefit from the project as a whole.

Table 3: AVOIDED CARBON EMISSIONS FROM THE BIOGAS PROJECT

Effect	Tons of Carbon or Carbon-Equivalent per Year
Avoided emissions from:	
Coal- and oil-fired electricity generation	198
Pig waste decomposition	1,300/a
Subtotal	**1,498**
Incremental emissions from:	
Methane-fired electricity generation	147
Net carbon emission reduction	**1,351**

/a Assuming a CH_4 global warming potential of 21.

Environmental Impacts of Renewable Energy

15. Renewable energy projects are not entirely environmentally benign and cause some environmental impacts of their own that offset the environmental benefits identified above. However, these offsetting impacts are orders of magnitude smaller than those of fossil fuel resources.

ANALYSIS OF ENVIRONMENTAL BENEFITS

16. The residual environmental impacts of a thermal power plant, after the installation of pollution control equipment or the mitigation of impacts via project design changes, represent external costs that are not reflected in the cost of the facility or the price of the

electricity that it produces. These "externalities" represent a real cost to society. From a societal perspective, an accurate assessment of electricity generation alternatives would incorporate these externalities. This type of analysis was beyond the scope of this report. However, it was felt that the report should at least refer to methodologies for incorporating environmental externalities into such analysis and how these methodologies might be applied to further assessments of renewable energy projects in China.

17. Much of the work on incorporating environmental externalities into electricity resource planning has occurred in the United States. Starting in the mid-1980s, electricity regulators began to require the incorporation of environmental externalities in utility resource planning processes. A 1994 survey revealed 26 states with externality assessment procedures and 24 without.[3] The various approaches to the assessment of environmental externalities can be divided into three groups: qualitative, quantitative and monetization.

18. The qualitative approach generally involves listing the types and rates of residual pollutants or environmental effects, describing their potential impacts and then characterizing these impacts, using categories such as "no impact," "moderate impact" and "substantial impact." This information is then subjectively factored into the resource selection process. In the 1994 survey, 10 states used this approach.

19. The quantitative approach involves assigning separate numerical scores to the financial, technical and environmental attributes of alternative resources, based on a predetermined methodology. These scores are then used in a "rating and weighting" process to judge the various alternatives. For instance, resources might be evaluated based on their cost, reliability and environmental impact using a weighting of 70/15/15, respectively. Each alternative would be scored within each category and the one that receives the highest overall score would be preferred. In the 1994 survey, seven states used this approach.

20. Finally, in the monetization approach, environmental externalities are assigned a monetary value which is added to the economic or financial cost of supply-side resources. Monetary values can be assigned using percentage adders, specific currency values per unit of energy or monetized values for specific emissions. In the 1994 survey, nine states used the monetization approach. Washington State used the percentage adder approach, adding 10 percent to the assessed cost of proposed coal-fired thermal plants. New York's utility commission issued dollar values per unit of energy for various impacts, presented in the following table. And California issued dollar values per physical unit of various air emissions, presented in Table 5. The California regulatory commission varied the assessed costs based on the location of the facility in order to take into account differences in air quality.

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[3] US General Accounting Office, 1995, *Electricity Supply: Consideration of Environmental Costs in Selecting Fuel Sources*, GAO/RCED-95-187.

Table 4: EXTERNAL COST VALUES IN NEW YORK STATE, 1990
(1990 US cents per kWh)

Externality	External Cost
Sulfur oxides	0.250
Nitrogen oxides	0.550
Particulate	0.100
Carbon dioxide	0.005
Impacts on water	0.100
Impacts on land	0.400

Source: US General Accounting Office.

Table 5: EXTERNAL COST VALUES IN CALIFORNIA, 1993
(1990 $'000 per ton)

Location of Facility	Nitrogen oxides	Sulfur dioxide	Particulate	Reactive organic gases	Carbon
Southern CA	44.4	33.1	9.6	31.7	0.044
Northern CA	12.9	6.3	3.7	6.0	0.044
Outside CA	10.6	2.4	6.5	1.8	0.044

Source: US General Accounting Office

21. Adopting one of the above approaches in China would require varying levels of effort. A qualitative approach would be the easiest of the three and require little new research. A quantitative approach would require new research and analysis to assess and rate the environmental impact of various alternative resources. A monetization approach would require considerably more work to assess the costs of electricity resources on human health and the environment. This would involve documenting meteorological conditions and demographic patterns in the vicinity of proposed thermal power plants, conducting air quality modeling. Monetization would also require developing a methodology to value changes in human health and death rates.

22. In order to provide some indication of the range of environmental costs that might apply to coal-fired generation in China, the following table presents assessed costs using three different sets of externality values. The emissions estimates used to develop the table were calculated for a representative large coal-fired thermal plant in China (T66) without pollution control measures. The externality values come from studies in China and the United States. The Chinese values were generated by the World Bank/GEF study of greenhouse gas mitigation options and include only acute health impacts of total

suspended particles and sulfur dioxide.[4] The US values were developed for application to electricity resource acquisition in California and New York.[5] The US values correspond to air emissions in the northern parts of each state where the population is dispersed among rural areas, towns and small cities. This demographic pattern may mimic that in rural areas of China. The US values reflect both acute and chronic health impacts of a range of air pollutants from electricity generation.

23. Applying US data to China is problematic due to differences in background levels of pollution, morbidity and mortality and in the health effects of incremental air pollution. However, in the absence of China-specific, comprehensive health impact data, such an application is unavoidable.

24. Since the majority of the US externality values correspond to health impacts, and since the resulting health costs are based on US values for a statistical life and health care costs, they have been scaled downwards in the following table to coincide with the lower income levels in China. The reason for this scaling is due to the fact that environmental costs of air pollution are traditionally based on individuals' willingness to pay to avoid the risk of premature death and the costs of health care. And these values, in turn, are dependent on income levels. In this case, the values were scaled using the methodology used in the World Bank/GEF study. That study assumed a US value for preventing a statistical death of $3 million. This was scaled to $126,000 for China, or roughly one twenty-fourth the US value.[6]

Table 6: ENVIRONMENTAL COST OF COAL-FIRED GENERATION IN CHINA, BASED ON SELECTED EXTERNALITY VALUES
(1990 $)

Source	Externality Value ($/ton)				Assessed Environmental Cost (cents/kWh)
	Carbon	Total Suspended Particles	Sulfur Dioxide	Nitrogen Oxide	
China Greenhouse Gas Study	--	35	113	--	0.07
US studies /a					
California (Northern CA)	44	154	263	538	1.39
New York (Northern NY)	--	118	3	45	0.11

/a US values have been scaled downward to Chinese income levels.

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4 World Bank, 1994, *China: Issues and Options in Greenhouse Gas Control.* Subreport # 8: *Valuing the Health Effects of Air Pollution—Application to Industrial Energy Efficiency Projects in China*, p. 22.

5 California figures are from US General Accounting Office, 1995, *Electricity Supply: Consideration of Environmental Costs in Selecting Fuel Sources*, GAO/RCED-95-187. New York figures are from *New York State Environmental Externalities Cost Study*, prepared by RCG/Hagler, Bailly, Inc. for the Empire State Electric Energy Research Corporation, 1994.

6 World Bank, 1994, *China: Issues and Options in Greenhouse Gas Control.* Subreport # 8: *Valuing the Health Effects of Air Pollution—Application to Industrial Energy Efficiency Projects in China*, p. 18.

25. The assessed cost of coal-fired generation in China range from 0.07 to 1.39 cents per kWh. The lowest assessed cost corresponds to the China greenhouse gas study externality values, partly because they are low and partly because they apply to only particulates and sulfur dioxide. The highest cost corresponds to the California estimates because they are higher and cover all four types of air emissions. It is impossible at this point to judge what would be appropriate or accurate externality values for China. However, the values for particulate and sulfur dioxide would be important given that many Chinese cities suffer from ambient levels of these pollutants that exceed WHO standards. With the growth of transportation in China, nitrogen oxides and resulting low-level ozone could become a problem in the future as well. And carbon emissions are of concern wherever they occur.

26. From the figures in the table it is clear that there are large differences between estimates of externality values. These differences can be attributed to differences in methodology or location of the studied effects. Take total suspended particles (particulates) for example. The Chinese value is $35 per ton, roughly one-quarter that of the scaled values from the United States. Part of this difference can be attributed to the fact that the Chinese value is based solely on the acute health effects of particulates, whereas the US values are based on both acute and, arguably more important, chronic effects.

27. Another example of a large difference is that between the two US values for sulfur dioxide, which differ by a factor of almost 100. This is because the New York sulfur dioxide externality value reflects only material damages. Health damages from sulfur dioxide in New York are included in the particulate externality value. California, on the other hand, values the health damages of particulates and sulfur dioxide separately. Yet another example is that between the two US values for nitrogen oxide, which differ by a factor of 12. The California figure is based on air quality in the San Francisco Bay area where low-level ozone is the leading air quality problem. Nitrogen oxide is one of the two primary precursors to ozone and is therefore assigned a high externality value. Ozone is not a problem in northern New York state, so nitrogen oxide emissions are assigned a lower value there.

28. The World Bank has begun to assess the health costs of air pollution in Asian countries. Over the last few years, it has conducted assessments of the health costs of air pollution in Jakarta,[7] Bangkok[8] and China.[9] The Jakarta study estimated the value of selected air pollutants in Jakarta at $220 million per year. The Bangkok study valued a 20

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[7] World Bank, 1993, *Indonesia—Energy and Environment: A Plan of Action for Pollution Control, Appendix 1*. Country Department III, East Asia and Pacific Region. June 30, 1993.

[8] Lakdasa Wijetilleke and Suhashini A.R. Karunaratne, 1995, *Air Quality Management: Considerations for Developing Countries*. World Bank Technical Series Paper Number 278, Energy Series.

[9] World Bank, 1994, *China: Issues and Options in Greenhouse Gas Control. Subreport # 4: Energy Efficiency in China: Case Studies and Economic Analysis.*

percent improvement in air quality at $0.75 billion to $3.1 billion per year. The China study estimated the health cost of particulate and sulfur dioxide emissions in a representative Chinese city at Y 165 and Y 530 per ton, respectively. In 1990 dollars, these values are equal to $35 and $113 per ton, respectively.[10] These figures are preliminary and highly conservative since they are based on 360-degree dispersion of pollutants, a simple pollution dispersion model, a 10-kilometer limit on health effects and acute health effects only. A more accurate assessment would take into account local meteorological and demographic data, involve more sophisticated air quality modeling over a wider area and incorporate chronic health effects in addition to acute effects. Unfortunately, this analysis involves considerable time and effort and therefore represents a barrier to more accurate estimation of environmental externalities in China.

Local Environmental Benefits of Renewable Energy Projects using Proxy Externality Values

29. In order to estimate the order of magnitude of local environmental benefits associated with the renewable energy case study projects, this annex calculates the value of avoided local air emissions generated by each project using two sets of proxy externality values derived from the China and US studies. It also reports a sensitivity analysis of the project's economic internal rate of return (EIRR) using the calculated local environmental benefits.

30. The following table presents the proxy externality values that were used in the following analysis. A high and low set of values for local health effects of air emissions were developed to establish a range within which actual values might reside. The high and low values for total suspended particles, sulfur dioxide and nitrogen oxide are within the range of the China and US studies listed in Table 6. These values and the resulting estimates of environmental benefits are indicative only. Further research and analysis is required to generate more accurate estimates of the value of cleaner air in China.

Table 7: PROXY EXTERNALITY VALUES
(1996 $ per ton)

Set	Total Suspended Particles	Sulfur Dioxide	Nitrogen Oxide
High	100	150	300
Low	35	113	100

10 Ibid., p. 18.

31. These proxy externality values were used to calculate the following value of avoided local air emissions. They assume that the renewable energy project offset coal- and oil-fired generation plants that are fitted with particulate and nitrogen oxide pollution control equipment.

Table 8: VALUE OF AVOIDED LOCAL AIR EMISSIONS
(cents per kWh)

Project	Set of Values	Total Suspended Particles	Sulfur Dioxide	Nitrogen Oxide	Total
Wind - Inner Mongolia	High	0.01	0.06	0.06	0.13
	Low	0.00	0.04	0.02	0.07
Wind - Guangdong	High	0.03	0.09	0.05	0.18
	Low	0.01	0.07	0.02	0.10
Bagasse - Guangxi	High	0.04	0.12	0.06	0.22
	Low	0.01	0.09	0.02	0.12
Biogas - Beijing	High	0.00	0.04	0.06	0.10
	Low	0.00	0.03	0.02	0.05

32. The value of avoided local air emissions range from a low of 0.05 cents per kWh for low-valued air emissions associated with the biogas project to a high of 0.22 cents per kWh for high-valued air emissions associated with the bagasse project.

33. Finally, the above values for avoided local air emissions were used to assess the sensitivity of the projects' EIRR to local environmental benefits. They were converted into annual streams of benefits and added to the economic cash flow of each project. Table 9 presents estimates of each project's EIRR with and without these benefits.

Table 9: PROJECT EIRRS WITH AND WITHOUT LOCAL ENVIRONMENTAL BENEFITS

		EIRR (%)	
Project	Set of Values	Excluding Local Environmental Benefits	Including Local Environmental Benefits
Wind-Inner Mongolia	High	10.5	13.4
	Low	10.5	12.0
Wind - Guangdong	High	5.4	6.2
	Low	5.4	5.9
Bagasse - Guangxi	High	32.9	34.5
	Low	32.9	33.8
Biogas - Beijing	High	18.3	18.6
	Low	18.3	18.4

34. As shown by the figures in the table, renewable project EIRRs are sensitive to the value of local environmental benefits. Crediting the wind project in Inner Mongolia with low-valued avoided air emissions added 1.5 percent to its baseline EIRR of 10.5 percent.

ANNEX 3: ORGANIZATION CHARTS FOR THE SOLAR HOME SYSTEM PROGRAM

Figure 1: PROJECT ORGANIZATION CHART

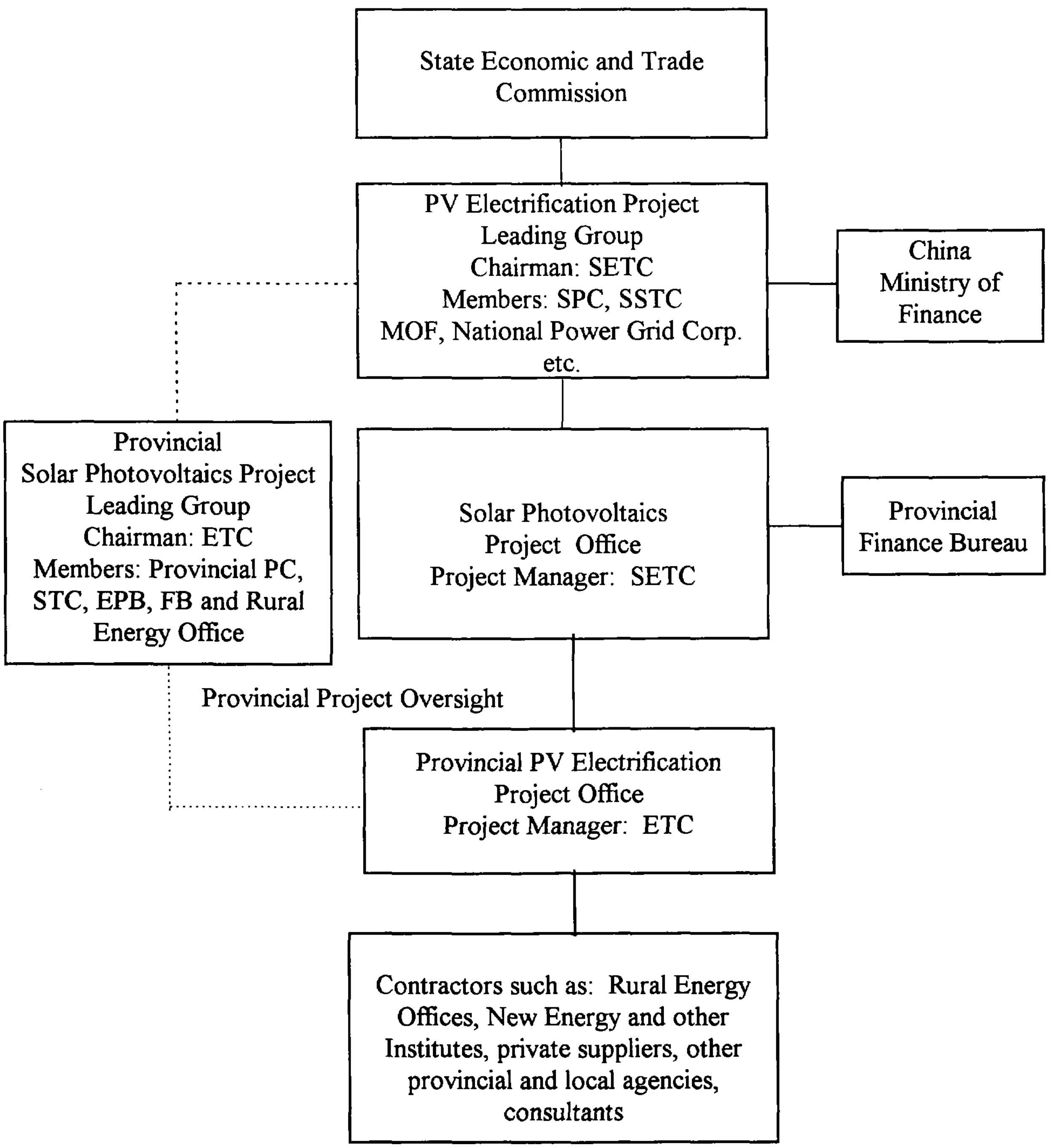

Figure 2: FINANCIAL FLOWS: SOLAR HOME SYSTEMS COMPONENT

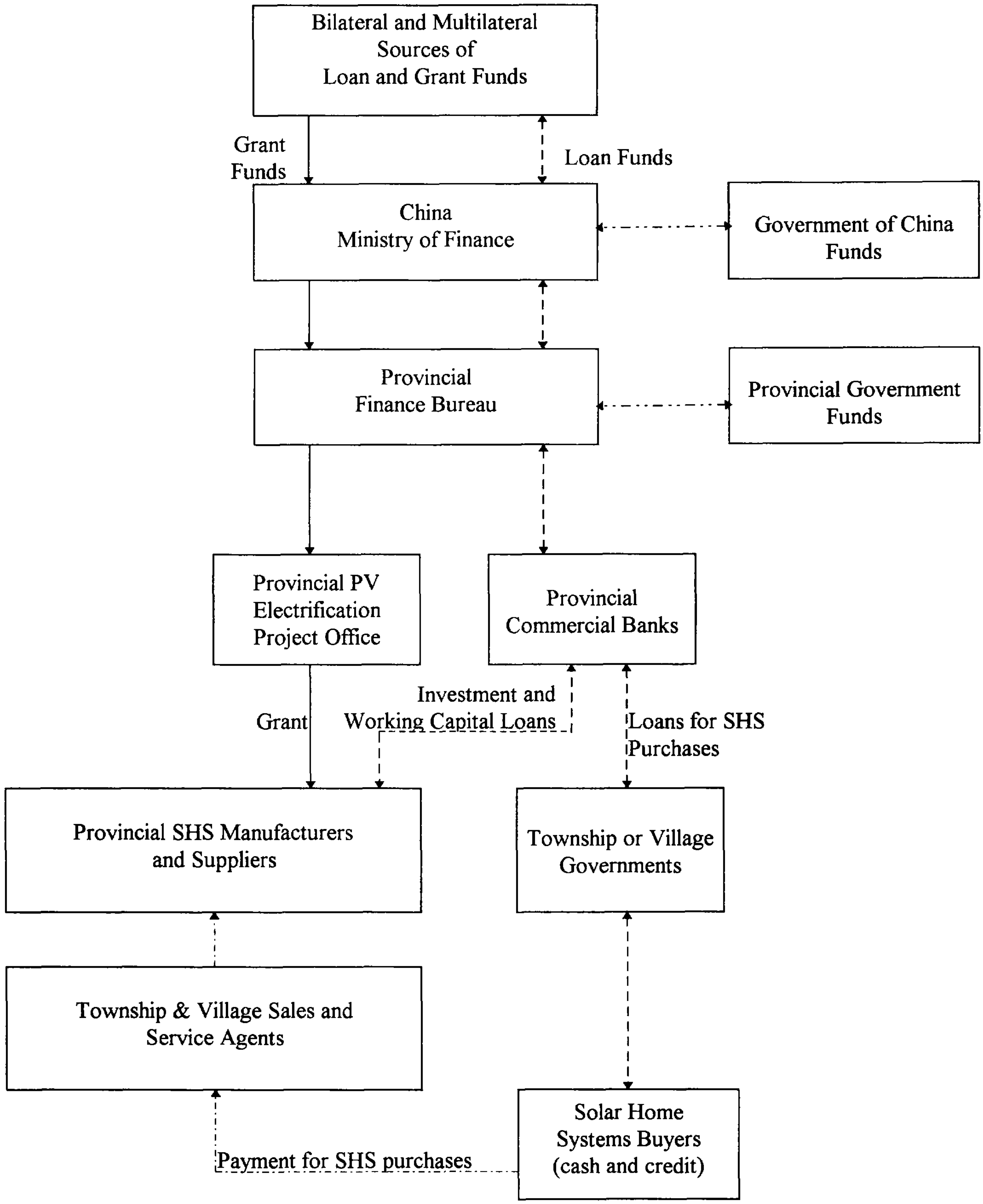

Table 1: ORGANIZATIONAL RESPONSIBILITIES

Organization	Responsibilities
Solar Photovoltaics Project Leading Group Chairman: State Economic and Trade Commission	• Responsibility for Project at Central Government-level • Interagency coordination and resolution of issues • Reporting to international financing/grant agencies • Members of Leading Group include: SPC, SSTC, MOF, National Power Grid Corporation, etc.
PV Electrification Project Office Project Manager: SETC	• Planning and coordination • Project management, supervision and monitoring • Technical assistance at national level, including appraisal assistance to banks • Dispute resolution • Reporting to National-level Leading Group
Provincial PV Electrification Project Leading Group Chairman: ETC	• Project oversight at Provincial Government-level • Provincial interagency coordination. and issues resolution. E.g. Coordination with EPB and other relevant provincial agencies on rural electrification plans and disbursement of grants • Reporting to national-level Leading Group • Members of Leading Group include: PC, STC, FB, EPB
Ministry of Finance Provincial Finance Bureau	• MOF onlends loans and disburses grant funds obtained from international agencies through Provincial Finance Bureau • Ensures loan agreement terms and conditions are met • Ensures grant agreement terms and conditions are met.
Provincial PV Electrification Project Office Project Manager: ETC	• Planning and coordination of SHS component • Project management, supervision and monitoring of SHS component • Assess product quality and service through testing & surveys • Verify installations and issue grant disbursements to suppliers • Provide technical assistance, including appraisal assistance to banks, training, information dissemination • Dispute resolution • Reporting to Provincial Leading Group
Provincial Electric Power Bureau	• Planning and coordination of centralized PV component • Coordination with SHS team on rural electrification • Project management, supervision and monitoring of centralized PV component • Reporting to Provincial Leading Group
Commercial Banks	• Onlend funds obtained via MOF/Provincial Power Bureau from international agencies • Supply local financing • Finance plant and machinery investments • Provide working capital loans to SHS manufacturers • Finance SHS through loans to village committee, and township governments
Manufacturers and Suppliers	• Receive loan funds from banks for investment and working capital • Upgrade manufacturing capability • Upgrade product quality and obtain product certifications
Township Governments and Village Committees	• Organize & qualify SHS customers wishing to buy for credit • Obtain SHS loan on behalf of customers • Guarantee loan to bank
Township and Village Sales and Service Agents	• Stock and sell certified SHS from suppliers • Train/educate users • Provide maintenance and repair services and stock spare parts • Submit receipts to SHS Project Management Office for issuing grants

ANNEX 4: ECONOMIC AND FINANCIAL CASHFLOWS FOR CASE STUDY ANALYSIS

Wind Power Case Study: Huitengxile
First Phase: 20/100 MW

WIND POWER CASE STUDY-- HUITINGXILE, Inner Mongolia

Table 1.Project profile

Name	Huitengxile Wind Mill (1st Phase)
Location	Inner Mongolia Automonous Region
Specification of Power Generator	Z-40/550
Total Installation (kW)	19800.00
Annual Prduction (GWH/a)	67.01
Capacity Utlizing Factor (%)	38.6%
Avoided Cost of Power (Yuan/MWh)	321.04
Power Sales Price (yuan/MWh)	745.00 (With VA Tax)
Exchange rate	8.30
Interest rate of loan (%/a)	15%
Share of Loan	70%
Term of Loan (Year)	10
Depreciation rate	8%
Import Duty	12%
VAT on Imports	17%
Capacity of the first year	100%
Miscellaneous labor costs	200%
Value added tax rate on output	17%
Value added tax rate on input	17%
VAA tax rate	8%
Income tax rate	33%
Standard Discount Rate	12%

Inflation Rate	1996	1997	1998	1999	2000	After 2000
	10.50%	8.50%	7.00%	6.50%	6.20%	6.20%

Number of Turbines	3600%
International Inflation	2.5%
Turbine Cost (US$/kwh including 10% towers)	800
Maintenance Cost/Turbine (US$)	8000

Table 2 Calculation of Avoided Cost

ANNUAL AVOIDED COST BENEFIT	Total 10^3 Yuan	Per Unit Yuan/kWh
Energy	21513.43	0.32
Energy & Capacity-- 100% Capacity Credit	30893.69	0.46
Energy and Capacity--30% Capacity Credit		0.38

	Dry Season			Wet Season			
	Peak	Mid-Peak	Off-Peak	Peak	Mid-Peak	Off-Peak	
AVOIDED COSTS BY RATING PERIOD (1995 Yuan/kWh):							
Energy	0.3835		0.1520	0.3835		0.1520	
Energy & Capacity	0.5752		0.1520	0.5752		0.1520	
GENERATION DELIVERED BY MONTH (MWh)	Adjusted		Adjusted				
January	5383		2501				
February	3484		1251				
March	4735		1653				
April	5271		1295				
May	6164		2189				
June	2635		893				
July	2412		849				
August	2099		804				
September	3752		1027				
October	3975		1608				
November	4199		1787				
December	4823		2222				
TOTAL kWh PER PERIOD	48932.00		18079.00			0.00	67011.00

1/ Network defined as: VHV (500/220 kV), HV (110/35 kV and above), MV (10/6 kV), LV (<1 kV)
2/ Rating period:

Peak	Mid-Peak	Off-Peak	Dry Season
07:00-22 59		23:00-06:59	all months weighted equally

Wind Power Case Study: Huitengxile
First Phase: 20/100 MW

Table 3 Capital Cost (million Rmb)

	Financial			Economic					
	Foreign Cost*	Local Cost	Total	Foreign Cost*	Local Cost	Total			
	-----	-----	-----	-----	-----	-----			
Equipment	118.32	13.15	131.47	118.32	13.15	131.47			
Duty and Tax	0.00	39.14	39.14			0.00			
Building		4.06	4.06		4.06	4.06			
Other	0.00	6.00	6.00	0.00	6.00	6.00			
Contingency	0.00	1.65	1.65	0.00	1.65	1.65			
T&D	0.00	7.00	7.00	0.00	7.00	7.00			
Capital Cost Before Finance	118.32	71.00	189.32	118.32	31.86	150.18		750.91	90.47
Loan Interest	0.00	19.88	19.88						
Total Capital Cost with Finance	118.32	90.88	209.20						
Total Fixed Asset			189.32					946.62	114.05
Total Liability			146.44						
Unit Investment (Yuan/kW)			9561.81	1152.03		7584.95	913.85		

Note: *It is assumed that FC is consisted totally of power generator and automatic control system.

Table 4. Operating cost (10^6 Yuan)

	Financial	Ecoonomic
1.Salary & Welfare	0.19	0.19
1.1 Number of workers	17.00	17.00
1.2 Annual salary (yuan/p)	10000.00	10000.00
1.3 Welfare rate	14%	14%
2. Maintenance	3.33	2.39
3. Other	0.39	0.39
4. Total	3.91	2.97

Table 5. Economic Cashflow (10^6 Constant Yuan)

Year	Capital Cost	Operating Cost	Income	Net Benefit
---------	---------	---------	---------	---------
1	150.18		0.00	-150.18
2		2.97	21.51	18.54
3		2.97	21.51	18.54
4		2.97	21.51	18.54
5		2.97	21.51	18.54
6		2.97	21.51	18.54
7		2.97	21.51	18.54
8		2.97	21.51	18.54
9		2.97	21.51	18.54
10		2.97	21.51	18.54
11		2.97	21.51	18.54
12		2.97	21.51	18.54
13		2.97	21.51	18.54
14		2.97	21.51	18.54
15		2.97	21.51	18.54
16		2.97	21.51	18.54
17		2.97	21.51	18.54
18		2.97	21.51	18.54
19		2.97	21.51	18.54
20	0.00	2.97	21.51	18.54
Total	150.18	56.46	408.76	202.11
NPV	134.09	21.89	141.48	-12.15
IRR				**10.5%**

Wind Power Case Study: Huitengxile
First Phase: 20/100 MW

Table 6. Financial Cashflow (10^6 Constant Yuan)

Year	Capital Cost	Operating Cost	Gross Income	VA & VAA Tax	Net Benefit
1	189.32	0.00	0.00	0.00	-189.32
2		3.91	45.18	7.72	33.55
3		3.91	41.64	7.07	30.66
4		3.91	38.92	6.57	28.44
5		3.91	36.54	6.13	26.50
6		3.91	34.41	5.74	24.76
7		3.91	32.40	5.37	23.12
8		3.91	30.51	5.02	21.57
9		3.91	28.73	4.70	20.12
10		3.91	27.05	4.39	18.75
11		3.91	25.47	4.10	17.46
12		3.91	23.98	3.83	16.25
13		3.91	22.58	3.57	15.10
14		3.91	21.26	3.33	14.03
15		3.91	20.02	3.10	13.01
16		3.91	18.85	2.88	12.06
17		3.91	17.75	2.68	11.16
18		3.91	16.72	2.49	10.31
19		3.91	15.74	2.31	9.52
20	0.00	3.91	14.82	2.14	8.77
Total	189.32	74.32	512.58	83.13	165.80
NPV	169.04	25.73	212.46	35.21	-17.51
IRR					**9.8%**

Table 7. Financial Cash Flow With Inflation, Debt Financing, Income Tax (10^6 Current Yuan)

Year	Investment			Operating Cost	Total Cost	Gross Income	VA£VAA Tax	Income Tax	Net Benefit
	Equity	Loan Principal	Loan Interest						
1	56.80				56.80			0.00	-56.80
2		14.64	21.97	4.32	40.93	49.92	8.53	0.15	0.31
3		14.64	19.77	4.69	39.10	49.92	8.47	0.77	1.57
4		14.64	17.57	5.02	37.24	49.92	8.42	1.41	2.86
5		14.64	15.38	5.33	35.35	49.92	8.38	2.04	4.15
6		14.64	13.18	5.68	33.50	49.92	8.33	2.67	5.42
7		14.64	10.98	6.03	31.65	49.92	8.28	3.30	6.70
8		14.64	8.79	6.40	29.83	49.92	8.22	3.92	7.95
9		14.64	6.59	6.80	28.03	49.92	8.16	4.53	9.20
10		14.64	4.39	7.22	26.26	49.92	8.10	5.14	10.43
11		14.64	2.20	7.67	24.51	49.92	8.03	5.74	11.65
12			0.00	8.14	8.14	49.92	7.96	11.16	22.66
13				8.65	8.65	49.92	7.89	11.02	22.37
14				9.18	9.18	49.92	7.81	10.87	22.06
15				9.75	9.75	49.92	7.73	10.71	21.74
16				10.36	10.36	49.92	7.64	10.54	21.39
17				11.00	11.00	49.92	7.54	10.36	21.03
18				11.68	11.68	49.92	7.44	10.16	20.64
19				12.41	12.41	49.92	7.33	9.96	20.22
20				13.18	13.18	49.92	7.22	12.77	16.76
Total	56.80	146.44	120.81	153.50	477.55	948.54	151.48	127.21	-158.04
NPV	50.71	82.74	79.62	48.74	239.20	367.72	60.32	28.69	-193.60
IRR									**13.3%**

Table 8 Calculation of Net Profit and Income Tax, for Cashflow (million current yuan)

Year	Interest	Depreciation	Total Operating	Total Cost	Gross Income	VA & VAA	Net income	Income Tax
1		0.00	0	56.80		0.00	-56.80	0.00
2	21.97	15.15	4.32	40.93	49.92	8.53	0.46	0.15
3	19.69	15.15	4.69	39.10	49.92	8.47	2.35	0.77
4	17.42	15.15	5.02	37.24	49.92	8.42	4.26	1.41
5	15.15	15.15	5.33	35.35	49.92	8.38	6.19	2.04
6	12.88	15.15	5.68	33.50	49.92	8.33	8.10	2.67
7	10.61	15.15	6.03	31.65	49.92	8.28	9.99	3.30
8	8.33	15.15	6.40	29.83	49.92	8.22	11.87	3.92
9	6.06	15.15	6.80	28.03	49.92	8.16	13.73	4.53
10	3.79	15.15	7.22	26.26	49.92	8.10	15.57	5.14
11	1.52	15.15	7.67	24.51	49.92	8.03	17.38	5.74
12	-0.75	15.15	8.14	8.14	49.92	7.96	33.82	11.16
13		15.15	8.65	8.65	49.92	7.89	33.39	11.02
14		12.79	9.18	9.18	49.92	7.81	32.93	10.87
15		7.50	9.75	9.75	49.92	7.73	32.44	10.71
16		0.00	10.36	10.36	49.92	7.64	31.93	10.54
17		0.00	11.00	11.00	49.92	7.54	31.38	10.36
18		0.00	11.68	11.68	49.92	7.44	30.80	10.16
19		0.00	12.41	12.41	49.92	7.33	30.18	9.96
20		0.00	13.18	13.18	49.92	-1.95	38.69	12.77
Total	116.68	202.04	153.50	477.55	948.54	142.32	328.67	127.21
NPV	77.88	87.75	43.51	239.20	367.72	52.90	36.22	28.69
IRR							17.9%	

Solar Home Systems Case Study

Table 1: Assumptions for SHS Economic and Financial Analysis Today

		Economic	Customs Duty	VAT, VAAT	Financial
Cost 20 Wp system today	(yuan)	1348	0	247	1595
Cost 20 Wp system 2001	(yuan)	1160	0	213	1373
Battery Cost	(yuan)	126	0	23	149
Bulb Cost	(yuan)	65	0	12	77
Controller Cost	(yuan)	211	0	39	250
Bulb Replacement	(years)	1			
Controller Replacement	(years)	10			
Battery Replacement	(years)	2			
VAT	%	17%			
VAAT	%	8%			
Value of Alternative Replaced		84.5			100
Subsidy		253.5			300
Discount Rate	%	12%			

Table 2: Assumptions for SHS Economic and Financial Analysis 2001

		Economic	Customs Duty	VAT, VAAT	Financial
Cost 20 Wp system 2001	(yuan)	1160	0	217	1377
Battery Cost	(yuan)	126	0	23	149
Bulb Cost	(yuan)	60	0	11	71
Controller Cost	(yuan)	150	0	28	178
Bulb Replacement	(years)	1			
Controller Replacement	(years)	10			
Battery Replacement	(years)	2			
VAT	%	17%			
VAAT	%	8%			
Value of Alternative Replaced		84.5			100
Subsidy		0.0			0
Discount Rate	%	12%			

Table 3: Economic Viability of 20 Wp System Today (constant 1995 yuan)

Years	Capital Cost	Battery Replace.	Bulb Replace.	Total SHS Lifecycle	Cost Alternative	Subsidy	Willingness Annual	Total Benefit
1	1348			1348	84	253	205	543
2		126	65	191	84		205	290
3			65	65	84		205	290
4		126	65	191	84		205	290
5			65	65	84		205	290
6		126	65	191	84		205	290
7			65	65	84		205	290
8		126	65	191	84		205	290
9			65	65	84		205	290
10		337	65	402	84		205	290
11			65	65	84		205	290
12		126	65	191	84		205	290
13			65	65	84		205	290
14		126	65	191	84		205	290
15			65	65	84		205	290
Total	1348	1093	910	3351	1267		3079	4347
NPV	$ 1,348	$ 778	$ 483	$ 2,296	$ 644	$ 253	$ 1,398	2296

Table 4: Economic Viability of 20 Wp System 2001 (constant 1995 yuan)

Years	Capital Cost	Battery Replace.	Bulb Replace.	Total SHS Lifecycle	Cost Alternative	Subsidy	Willingness Annual	Total Benefit
1	1160			1160	84	0	207	291
2		126	60	186	84		207	291
3			60	60	84		207	291
4		126	60	186	84		207	291
5			60	60	84		207	291
6		126	60	186	84		207	291
7			60	60	84		207	291
8		126	60	186	84		207	291
9			60	60	84		207	291
10		276	60	336	84		207	291
11			60	60	84		207	291
12		126	60	186	84		207	291
13			60	60	84		207	291
14		126	60	186	84		207	291
15			60	60	84		207	291
Total	1160	1032	840	3032	1267		3102	4369
NPV	$ 1,160	$ 739	$ 445	$ 2,053	$ 644	$ -	$ 1,409	2053

Table 5: Financial Viability of 20 Wp System Today (constant 1995 yuan)

Years	Capital Cost	Battery Replace.	Bulb Replace.	Total SHS Lifecycle	Cost Alternative	Subsidy	Willingnes Annual	Total Benefit
1	1595			1595	100	300	205	605
2		149	77	226	100		205	305
3			77	77	100		205	305
4		149	77	226	100		205	305
5			77	77	100		205	305
6		149	77	226	100		205	305
7			77	77	100		205	305
8		149	77	226	100		205	305
9			77	77	100		205	305
10		399	77	476	100		205	305
11			77	77	100		205	305
12		149	77	226	100		205	305
13			77	77	100		205	305
14		149	77	226	100		205	305
15			77	77	100		205	305
Total	1595	1294	1077	3966	1500		3079	4579
NPV	$ 1,595	$ 921	$ 571	$ 2,718	$ 763	$ 300	$ 1,655	2718

Table 6: Financial Viability of 20 Wp System 2001 (constant 1995 yuan)

Years	Capital Cost	Battery Replace.	Bulb Replace.	Total SHS Lifecycle	Cost Alternative	Subsidy	Willingnes Annual	Total Benefit
1	1377			1377	100	0	205	305
2		149	71	220	100		205	305
3			71	71	100		205	305
4		149	71	220	100		205	305
5			71	71	100		205	305
6		149	71	220	100		205	305
7			71	71	100		205	305
8		149	71	220	100		205	305
9			71	71	100		205	305
10		327	71	398	100		205	305
11			71	71	100		205	305
12		149	71	220	100		205	305
13			71	71	100		205	305
14		149	71	220	100		205	305
15			71	71	100		205	305
Total	1377	1221	994	3593	1500		3079	4579
NPV	$ 1,377	$ 875	$ 527	$ 2,434	$ 763	$ -	$ 1,671	2434

Biogas Case Study

Case Study on Biogas

Table 1. Project Profile

Total Power Installed (kW)	314.57	
Efficiency	25%	
Annual Operation Hours	2920.00	
Gross Power Generation (MWh/yr)	918.53	
Power Self Use Rate	0.83%	
Net Power Generation (MWh/yr)	910.91	
Total Self Power Use (MWh)	7.62	
Power Developers After-Tax Revenue	500.00	
Power Sales Price (Yuan/MWh)	500	(includes VAT and VAAT)
Avoided Cost of Power (Yuan/MWh)	575.20	
Size of Digester (m^3)	500.21	
Annual Waste Processing (t)	70000.00	
Annual Gas Production (10^3 m^3)	700.00	
Gas Used for Power Generation (% of Gas Production)	90.00%	
Gas Used for Power Generation (10^3 m^3/yr)	630.00	
Gas Use for Power (m^3/MWh)	685.88	
Annual Fertilizer Production (t)	2000.00	
Fertilizer Sales Price (Yuan/t)	175.00	
Total Income of Fertilizer (10^3 Yuan)	350.00	
VAT on Inputs	17%	
Gas Sales (000m^3)	70.00	
Gas Price (y/m^3)	0.50	

Table 2. Calculation of Avoided Cost (MV)

ANNUAL AVOIDED COST BENEFIT	Total 10^3 Yuan	Per Unit Yuan/kWh
Avoided Energy Cost	349.33	0.3835
Total - Energy & Capacity	**524.0**	**0.575**

	Dry Season			Wet Season		
	Peak	Mid-Peak	Off-Peak	Peak	Mid-Peak	Off-Peak
AVOIDED COSTS BY RATING PERIOD (1995 Yuan/kWh):						
Avoided Energy Cost	0.3835	0.0000	0.1520	0.3835	0.0000	0.1520
Total - Energy & Capacity	0.5752	0.0000	0.1520	0.5752	0.0000	0.1520
GENERATION DELIVERED BY MONTH (MWh)						
January	75.91	0.00		0.00	0.00	0.00
February	75.91	0.00		0.00	0.00	0.00
March	75.91	0.00		0.00	0.00	0.00
April	75.91	0.00		0.00	0.00	0.00
May	75.91	0.00		0.00	0.00	0.00
June	75.91	0.00		0.00	0.00	0.00
July	75.91	0.00		0.00	0.00	0.00
August	75.91	0.00		0.00	0.00	0.00
September	75.91	0.00		0.00	0.00	0.00
October	75.91	0.00		0.00	0.00	0.00
November	75.91	0.00		0.00	0.00	0.00
December	75.91	0.00		0.00	0.00	0.00
TOTAL MWh PER PERIOD	910.91	0.00	0.00	0.00	0.00	0.00

1/ Network defined as: VHV (500/220 kV), HV (110/35 kV and above), MV (10/6 kV), LV (<1 kV).

2/ Rating periods:

	Peak	Mid-Peak	Off-Peak	Dry Season
- JJT	07:00-22:59		23:00-06:59	all months weighted equally

Biogas Case Study

Table 3. Main Assumption in Cash Flow Analysis

Economic IRR					12.0%
Financial IRR					12.0%
VAT Paid on Plant Revenue					0.0%
VAAT Paid on VAT					0.0%
Income Tax Rate					33.00%
Debt Investment					70.0%
Bank Loan Interest					15.0%
Pay Back Time (Years)					10.00
Depreciation Rate					7%
Inflation Rate					
1996	1997	1998	1999	2000	After 2000
10.50%	8.50%	7.00%	6.50%	6.20%	6.20%

Table 4. Investment of the Project (10^3 Yuan)

		Financial	Economic
Biogas Digester			
	1. Design	100.00	100.00
	2. Land	32.00	32.00
	3. Digestor	1000.00	854.70
	4. Gas Clean & Storage	500.00	427.35
	5. Others	100.00	100.00
Digestor Block Total		*1732.00*	*1514.05*
Power System			
	1. Generator	157.28	134.43
	2. Building	200.00	170.94
	3. Network Cost	100.00	85.47
	4. Gas Reticulation	0.00	0.00
Power System Total		*457.28*	*390.84*
Fertilizer System		800.00	683.76
Subtotal		2989.28	2588.65
Working Capital		199.27	0.00
Subtotal		3188.55	2588.65
Interest During Construction		478.28	0.00
Total		3666.83	2588.65

Table 5. Operating Cost (10^3 Yuan)

Items		Use (tonnes) Quantity	Units	Unit Price - Y (Financial)	Financial Cost	Economic Cost
Consumables						
	Coal	200.00	tonnes	250.00	50.00	42.74
	Water	1000.00	tonnes	0.30	0.30	0.26
	Desulphur	10.00	tonnes	4600.00	46.00	39.32
	Misc. Materials	6000.00	tonnes	10.00	60.00	51.28
	Total Consumables				156.30	133.59
Labor						
	Power Generation	3.00	Staff	300.00	10.80	10.80
	Biogas Production	4.00	Staff	300.00	14.40	14.40
	Fertilizer Production	9.00	Staff	300.00	32.40	32.40
	Manager	1.00	Staff	500.00	6.00	6.00
	Total Salary Per Year				63.60	63.60
Welfare		20.00%	of salary		12.72	12.72
Management		33.33%	of salary + welfare		25.44	25.44
Total Labor Cost					101.76	101.76
Maintenance		5.00%	of fixed asset and work capital		159.43	136.26
Total					**417.49**	**371.61**

Table 6. Economic Cash Flow Analysis (10^3 Yuan)

Year	Invest.	Operating Cost					Incomes				Net Benefit
		Consumables	Mainten.	Labor	Sub total	Total Cost	Fertilizer	Power	Gas	Total	
1	*2588.65*				*0.00*	*2588.65*					*-2588.65*
2		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
3		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
4		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
5		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
6		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
7		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
8		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
9		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
10		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
11		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
12		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
13		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
14		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
15		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
16		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
17		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
18		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
19		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
20		133.59	136.26	101.76	371.61	371.61	350.00	523.95	35.00	908.95	537.34
Total	2588.65	2538.21	2588.99	1933.44	7060.64	9649.29	6650.00	9955.13	665.00	17270.13	7620.84
NPV	2588.65	1102.07	1124.12	839.49	2737.21	5325.87	2887.38	4322.45	288.74	7498.57	1369.29
IRR											**18.48%**

Table 7.Financial Cash Flow without Inflation (10^3 Yuan)

Year	Investment	Operating Cost					Income						Saved	
		Consumables	Mainten.	Labor	Sub Total	Total Cost	Fertilizer	Power	Gas	Total	VA & VAA Tax	Net Benefit	Discharge Penalty	Net Benefit Less Discharge Penalty
1	3188.55				0.00	3188.55						-3188.55		-3188.55
2		156.30	159.43	101.76	417.49	417.49	350.00	412.18	35.00	797.18	0.00	379.69	16.80	396.49
3		156.30	159.43	101.76	417.49	417.49	350.00	379.89	35.00	764.89	0.00	347.40	16.80	364.20
4		156.30	159.43	101.76	417.49	417.49	350.00	355.03	35.00	740.03	0.00	322.55	16.80	339.35
5		156.30	159.43	101.76	417.49	417.49	350.00	333.36	35.00	718.36	0.00	300.88	16.80	317.68
6		156.30	159.43	101.76	417.49	417.49	350.00	313.90	35.00	698.90	0.00	281.41	16.80	298.21
7		156.30	159.43	101.76	417.49	417.49	350.00	295.58	35.00	680.58	0.00	263.09	16.80	279.80
8		156.30	159.43	101.76	417.49	417.49	350.00	278.32	35.00	663.32	0.00	245.83	16.80	262.63
9		156.30	159.43	101.76	417.49	417.49	350.00	262.07	35.00	647.07	0.00	229.58	16.80	246.38
10		156.30	159.43	101.76	417.49	417.49	350.00	246.77	35.00	631.77	0.00	214.28	16.80	231.08
11		156.30	159.43	101.76	417.49	417.49	350.00	232.37	35.00	617.37	0.00	199.88	16.80	216.68
12		156.30	159.43	101.76	417.49	417.49	350.00	218.80	35.00	603.80	0.00	186.31	16.80	203.11
13		156.30	159.43	101.76	417.49	417.49	350.00	206.03	35.00	591.03	0.00	173.54	16.80	190.34
14		156.30	159.43	101.76	417.49	417.49	350.00	194.00	35.00	579.00	0.00	161.51	16.80	178.31
15		156.30	159.43	101.76	417.49	417.49	350.00	182.67	35.00	567.67	0.00	150.19	16.80	166.99
16		156.30	159.43	101.76	417.49	417.49	350.00	172.01	35.00	557.01	0.00	139.52	16.80	156.32
17		156.30	159.43	101.76	417.49	417.49	350.00	161.97	35.00	546.97	0.00	129.48	16.80	146.28
18		156.30	159.43	101.76	417.49	417.49	350.00	152.51	35.00	537.51	0.00	120.02	16.80	136.82
19		156.30	159.43	101.76	417.49	417.49	350.00	143.61	35.00	528.61	0.00	111.12	16.80	127.92
20		156.30	159.43	101.76	417.49	417.49	350.00	135.22	35.00	520.22	0.00	102.74	16.80	119.54
Total	3188.55	2969.70	3029.12	1933.44	7932.26	11120.81	6650.00	4676.28	665.00	11991.28	0.00	870.47	319.20	1189.67
NPV	3188.55	1289.42	1315.22	839.49	3075.12	6263.67	2887.38	2431.39	288.74	5607.51	0.00	-1256.96	138.59	-1133.21
IRR												**4.53%**		**5.662%**

Bagasse Cogeneration
Case Study

Table 1 - Technical/Economic/Financial Assumptions

Cane Capacity (tcpd)		5000
Pressure (MPa)		4.9
Excess Capacity (kW)		9000
ton bagasse/ton cane		0.428
bagasse (ton per day)		2140
"excess" bagasse (% of total)		10%
"excess" bagasse (ton/day)		214
season length (days)		180
"excess" bagasse (ton/season)		38520
Availability		81%
Generation (GWh)		31.49
VAT on Input		17%
discount rate		12.0%
VAT on plant revenue		17%
VAAT on VAT on plant rev.		8%
Cap Cost Alloc. (% of total)		70%
Inflation Table		
	1996	10.50%
	1997	8.50%
	1998	7.00%
	1999	6.50%
	2000	6.20%
	post-2000	6.20%

Table 2 - Avoided Cost Calculation

	Peak	Mid-peak	Off-Peak	Total
Hrs/day	6	11	7	24
Avoided cost (Y/kWh)	0.864	0.4329	0.2921	
Weighting factor	5.184	4.7619	2.0447	
average avoided cost (Y/kWh)				0.500

Table 3 - Cost Data

	Financial	Economic
Capital Costs		
Boiler cost ('000Y)	16,664	14,243
Turbine cost ('000Y)	44,373	37,926
Total Capital ('000Y)	61,037	52,168
Cap Cost Alloc. (% of total)	70%	
Case Study Cap. Cost ('000Y)	42,726	36,518
O&M		
percent of capital cost/yr	10%	10%
000Y/yr	4,273	3,652
Opportunity Cost		
Y/ton	0	0.0
000Y/yr	0	0.0
Revenue/Avoided Cost		
Unit price (Y/kWh)	0.510	0.500
Pre-tax pwr purch price (Y/kWh)	0.668	
Revenue/Avoided Cost ('000Y/yr)	21033.69	15734.07

Bagasse Cogeneration
Case Study

Table 4 - Economic Analysis ('000 Y)

		Capital	O&M	Opportunity Cost	Avoided Power Cost	Net Revenue	Discounted Revenue (12%)
1		36,518				(36,518)	-36518
2			3,652	-	15734	12,082	10788
3			3,652	-	15734	12,082	9632
4			3,652	-	15734	12,082	8600
5			3,652	-	15734	12,082	7679
6			3,652	-	15734	12,082	6856
7			3,652	-	15734	12,082	6121
8			3,652	-	15734	12,082	5465
9			3,652	-	15734	12,082	4880
10			3,652	-	15734	12,082	4357
11			3,652	-	15734	12,082	3890
12			3,652	-	15734	12,082	3473
13			3,652	-	15734	12,082	3101
14			3,652	-	15734	12,082	2769
15			3,652	-	15734	12,082	2472
16			3,652	-	15734	12,082	2207
17			3,652	-	15734	12,082	1971
18			3,652	-	15734	12,082	1760
19			3,652	-	15734	12,082	1571
20			3,652	-	15734	12,082	1403
	Total	36,518	69,384	-	298,947	193,045	52,477
						IRR =	33%

Table 5 - Financial Analysis w/o inflation

		Capital	O&M	Opportunity Cost	Power Sales Revenue	VA & VAA Tax	Net Revenue	Discount Revenue (12%)
1		42,725.98					(42,725.98)	-42726
2			4,273	0	19,035	2768.5	11,993.93	10709
3			4,273	0	17,544	2494.7	10,776.50	8591
4			4,273	0	16,396	2284.0	9,839.49	7004
5			4,273	0	15,395	2100.2	9,022.52	5734
6			4,273	0	14,497	1935.2	8,288.75	4703
7			4,273	0	13,650	1779.8	7,597.82	3849
8			4,273	0	12,853	1633.5	6,947.22	3143
9			4,273	0	12,103	1495.8	6,334.61	2558
10			4,273	0	11,396	1366.0	5,757.76	2076
11			4,273	0	10,731	1243.9	5,214.59	1679
12			4,273	0	10,105	1128.9	4,703.13	1352
13			4,273	0	9,515	1020.6	4,221.52	1084
14			4,273	0	8,959	918.6	3,768.04	864
15			4,273	0	8,436	822.5	3,341.03	684
16			4,273	0	7,944	732.1	2,938.94	537
17			4,273	0	7,480	647.0	2,560.34	418
18			4,273	0	7,043	566.8	2,203.83	321
19			4,273	0	6,632	491.3	1,868.14	243
20			4,273	0	6,245	420.2	1,552.04	180
	Total	42,726	81,179	-	215,959	25,850	66,204	13,002