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China

*A Strategy for International Assistance
to Accelerate Renewable Energy Development*

*Robert P. Taylor
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to Accelerate Renewable Energy Development*

*Robert P. Taylor
V. Susan Bogach*

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FOREWORD

With China's coal use forecast to triple by 2020, the expansion of renewable energy technologies is urgently needed for local, regional and global environmental sustainability. Given the massive scale of energy use in China, it will take time for renewable energy to make a significant contribution to the energy balance. But action to deepen and accelerate the process must be taken now and sustained, in order to have a significant impact in the future. China is at a critical crossroads for action on renewable energy development. Action is urgently needed to develop market infrastructure, improve information access, improve commercial renewable energy capabilities, and put in place policies necessary to enable expansion of commercial markets.

China has taken up this challenge in various ways, including the preparation of the "The New and Renewable Energy Development Program 1996-2010" by three high level Commissions, the State Planning Commission (SPC), the State Economic and Trade Commission (SETC), and the State Science and Technology Commission (SSTC), and provision for renewable energy development under the Electricity Law of 1995.

This report summarizes recommended priority areas for international support to strengthen China's renewable energy development effort, drawing from the work of SETC and other Chinese government agencies, the World Bank and the United Nations Development Program (UNDP). The World Bank and UNDP are now preparing complementary programs to assist China in a number of priority areas, with financing in part from the Global Environment Facility (GEF). It is clear that additional resources for renewable energy development are needed from bilateral and multilateral development agencies, as well as nongovernmental organizations and the private sector to achieve a multipronged program.

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ABSTRACT

This report was prepared by the China Country Unit of the East Asia and Pacific Regional Office of the World Bank, assisted by the Asia Alternative Energy Unit, following extensive discussions with staff from China's State Economic and Trade Commission (SETC), many other Chinese agencies and groups, and the United Nations Development Program (UNDP). It represents a summary of the conclusions of two more extensive reports: (a) *China: Renewable Energy for Electric Power* (The World Bank, September 11, 1996), a joint study by the Bank and the Government of China coordinated by SETC; and (b) *China: Renewable Energy for Thermal Applications* (SETC, December 1996), a study with international consultant inputs and Bank staff advice, financed in part by the Global Environment Facility (GEF).

The report is intended to focus the attention of decisionmakers in bilateral and multilateral development agencies on the need for major investments and technical assistance efforts to support renewable energy development in China, and on priority areas for such assistance. Chapter 1 outlines the urgency of China's renewable energy development and explains how this report evolved from efforts to develop World Bank and UNDP renewable energy programs. Chapter 2 provides an overview of China's efforts to adopt and implement a more market-oriented renewable energy development strategy. Chapter 3 outlines general areas where international assistance can help strengthen policy development and institutional capacity building. Chapter 4 outlines China's development programs and priority areas for international assistance for eight promising renewable energy technologies:

- grid-connected wind farms;
- solar photovoltaics;
- solar hot water heating;
- bagasse cogeneration;
- biomass gasification for heat;
- biogas for power/effluent treatment;
- geothermal energy for heat; and
- geothermal energy for power.

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ABBREVIATIONS AND ACRONYMS

GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Global Imaging System
GW	Gigawatt
IPP	Independent Power Producer
kW	Kilowatt
MW	Megawatt
MWP	Megawatt-peak
PV	Photovoltaic
R&D	Research and Development
SETC	State Economic and Trade Commission
SHS	Solar Home Systems
SPC	State Planning Commission
SSTC	State Science and Technology Commission
UNDP	United Nations Development Program

CHAPTER 1. INTRODUCTION

Renewable energy development in China is at a critical crossroads. With large increases in energy demand a certainty over the long term, development of large-scale renewable energy supply is strategically important for local, regional and global environmental sustainability. Large-scale renewable energy supply will require reduction in costs, through technological advancement, efficiency gains, low-cost equipment manufacturing and scale economies. Financing requirements and efficiency concerns dictate that development should be undertaken through the market. This also requires concerted action, especially in the case of China, to develop market infrastructure, improve information access, improve commercial capabilities in the renewable energy field, and put in place efficient market-based incentives where necessary. The scale of development needed to make a meaningful contribution to the environmental agenda will require time. But expanded action to deepen and accelerate the development process must be taken now, and sustained: given the nature of the challenge, there is no time to wait for "events to take care of themselves."

This paper provides a summary of recommended priority areas for international donor agencies to assist China to strengthen its renewable energy development effort. Assistance is needed from different types of agencies, including the Global Environment Facility (GEF), United Nations system, the multilateral development banks, bilateral donor agencies and nongovernmental organizations, to achieve a multipronged, sustained assistance program. Clearly, development must rely on a host of Chinese companies and financing institutions, and the foreign private sector, to achieve the necessary technology gains and implement capital construction. However, although less important in terms of investment dollars, the role of the Government, assisted by international donor agencies where necessary, is critical to achieve the strategic agenda. International experience in the development of renewable energy, and a number of other major technology-intensive energy supply technologies, shows that strategically targeted public-sector support often makes the difference between success and failure to get off the ground.

This paper was prepared by the World Bank, following extensive discussions with China's State Economic and Trade Commission (SETC) and many other Chinese agencies and groups, and with staff from the United Nations Development Program (UNDP). The conclusions and recommendations are endorsed by SETC and represent a summary of the conclusions and recommendations presented in two more extensive reports: (a) *China: Renewable Energy for Electric Power* (The World Bank, September 1, 1996), a joint study by the Bank and Chinese Government (with coordination by SETC); and (b) *China: Renewable Energy Development Study for Thermal Applications* (SETC,

December 1996), a study completed by SETC with international consultant inputs and Bank staff advice, and financed in part by the GEF. UNDP and the World Bank are now preparing major complimentary programs to assist China in a number of the recommended areas, with financing in part from the GEF. UNDP's program focuses on assistance for capacity building, both at the integrated and national level, and for four specific technologies—solar photovoltaic (PV) hybrid systems for decentralized electric power, wind farms, medium- and large-scale anaerobic digestors, and bagasse cogeneration. The World Bank's program focuses on development of large-scale wind farms for grid-connected electric power, expansion of PV use through commercial development of solar-electric home systems, and support for development and implementation of priority research and development (R&D) initiatives. However, these two programs provide assistance in only some of the priority areas, and additional assistance from bilateral and other international donors is critically needed.

In the sections below, Chapter 2 provides an overview of China's efforts to adopt and implement a more market-oriented renewable energy development strategy. Chapter 3 outlines general areas where international assistance can help strengthen policy development and institutional capacity building. Chapter 4 outlines China's development programs for eight promising renewable energy technologies, and specific priority areas for international assistance.

CHAPTER 2. RENEWABLE ENERGY DEVELOPMENT STRATEGY

RENEWABLE ENERGY AND THE ENVIRONMENTAL AGENDA

China's economy is expected to continue to grow at rapid rates well into the next century. Even with an unprecedented reduction in energy intensity to one third of its current level, primary commercial energy consumption is expected to triple between 1990 and 2020, growing at an average rate of about 4 percent per year.¹ Coal, which is available in most parts of China at low cost and provides three-quarters of China's commercial energy, is expected to continue to dominate China's energy balance. Even with a fourfold increase in oil consumption, eightfold increase in natural gas consumption, and sevenfold increase in hydroelectric and nuclear power production, coal use would still need to provide about two-thirds of China's commercial energy in 2020. This corresponds to an increase in coal consumption from just over 1 billion tons in 1990 to 3 billion tons in 2020, with increasingly unsustainable pressure on the environment.

Even with dramatic declines in China's energy intensity, China's continued rapid economic growth can be expected to be accompanied by a threefold increase in greenhouse gas (GHG) emissions by around 2020 under most baseline scenarios. In addition, the forecast large increases in coal use also will even further exacerbate China's difficulties in mitigating problems of increasing acid rain and urban air quality levels, which are among the worst in the world. Addressing the severe problems of local air pollution, acid rain and GHG emissions associated with increasing coal use must involve a wide range of measures, including more aggressive energy conservation and adoption of improved coal utilization methods. The need for far more aggressive development of wide noncoal energy alternatives, however, is inescapable. While major improvements in energy efficiency can buy time, massive substitution of cleaner sources of energy for coal is ultimately required to meet growing energy demands in an environmentally sustainable way.

¹ Assumes an average growth in GDP of 8 percent per year, and an energy use/GDP growth elasticity of 0.5 sustained over the three decades of 1991-2020. For further description of the baseline scenario described in this paragraph, see *China: Issues and Options in Greenhouse Gas Emissions Control: Summary Report*. (Report of a Joint Study Team from the National Environmental Protection Agency of China, State Planning Commission of China, UNDP and the World Bank, December 1994).

Especially over the long term, there is a common consensus that renewable energy must begin to play a more meaningful role in meeting China's energy needs.² With the resource constraints that ultimately exist for oil, natural gas and hydropower development, most energy experts look to nuclear power and/or renewable energy as key new sources of energy supply. What must be more appreciated, however, is the scale of renewable energy development that will be required to have any impact on the environmental agenda: 1 percent of primary commercial energy supply in 2020 is equivalent to the baseload output of at least 16,000 megawatts (MW) of electric power plant capacity, requiring an investment in the range of US\$15.0-\$30.0 billion. For renewable energy to make an appreciable contribution, it will require a development program of an internationally unprecedented size.

DEVELOPMENT STRATEGY

Development of renewable energy supplies on the scale required to have an impact will require a sustained, long-term effort. With the technologies and development methods currently applied in China, the costs of most wind power, solar energy and new biomass development schemes are only financially competitive with conventional alternatives in certain niche applications. Moreover, the institutional/corporate and market infrastructure required for efficient commercialization of renewable energy technologies in China's evolving market has yet to be put in place. Renewable energy development has the potential to make a difference in China's energy future—China's natural conditions and resources are highly favorable. But realization of this potential will require a strong and steady effort to promote cost reduction and develop the infrastructure for large-scale commercialization. The priorities are to build up the policy framework, and institutional capacity, and carry out step-by-step development programs for each of the more promising technologies, to enable renewable energy technologies to more rapidly penetrate the market.

China has achieved progress in renewable energy development during the last two decades, with a wide variety of institutes, agencies and enterprises involved in many different programs. Generally speaking, however, development has not moved into the commercialization stage. Research and development institutions, typically supported with small amounts of government financial support, have had difficulty proceeding into real commercialization and achieving necessary scale economies. Where attempts were made at larger-scale development under the planned economy, support was targeted primarily at the creation of the manufacturing and technological infrastructure, with mixed results.

² Renewable energy is defined in this paper to exclude hydropower and traditional biomass fuel, which already make a major contribution to energy supply, and are the focus of other, additional and specific government development programs.

The Chinese Government has increased its commitment to renewable energy development, as outlined the Government's New and Renewable Energy Development Program, 1996-2010.³ The program has been jointly development by the three relevant Commissions—SETC, the State Planning Commission (SPC), and the State Science and Technology Commission (SSTC), as well as the relevant line ministries. Approved by the State Council in 1994, the program seeks to improve the efficiency of renewable energy technology, lower production costs, and enlarge the contribution of renewable energy in the energy system. Development programs to meet these objectives have been drawn up for each of the major technologies, including both R&D and commercialization programs.

The Government also recognizes that new approaches are now required. Development must be based upon the market system which is supplanting the planned economy. To capture the efficiency advantages of the market, commercial development must be based on market demand. Increasing market demand then provides the push to industry to further expand production, develop technology, expand the scope of application, and subsequently reduce costs. Investment must be made by enterprises themselves (using loan or equity financing), based on market forces. Competition and free entry into the market are important for development to be efficient. The government must retain an important role, but that role is different than under the previous system, and should focus on developing market infrastructure, fostering an efficient market environment, and targeted initiatives using market mechanisms to accelerate development in the public interest.

DEVELOPMENT CHALLENGES

Reducing Costs

While some applications of renewable energy are financially viable today, such as solar hot water heating for residential use in areas of high solar insolation, certain isolated applications of wind power generation or solar PV technologies, or certain types of biomass-fueled cogeneration, large-scale use of renewable energy technologies will require major reductions in cost. Viability of renewable energy compared with coal will improve with greater internalization of environmental costs associated with coal use, but this is likely to continue to be a gradual process. Cost reduction for renewable energy technologies is especially important because most of the cost of renewable energy systems is capital cost, requiring mobilization of large upfront investment financing in a capital-scarce economy. Significant cost reductions will require:

³ For further details, see, *China: Renewable Energy for Electric Power* (World Bank Report No. 15592-CHA, September 11, 1996), Chapter 2.

- **Achievement of Scale Economies.** Transition from pilot to larger-scale applications and from small-scale, often customized, production to mass-production technologies are expected to yield substantial cost reductions in the future. Scale economies and cost savings due to wider application scope are important in terms of increasing the size of units (e.g., wind-power turbines), increasing the scale of manufacturing (e.g., solar PVs), and increasing the scale of implementation.
- **Technological Advancement.** Often coupled with increasing scale economies, technology improvements also have been and are expected to continue to be a key source of unit cost reduction. For China, technology advancement involves a combination of transfer from abroad, often through joint-venture arrangements, and well targeted domestic R&D for certain technologies.
- **Improving the Efficiency of Project Design and Implementation.** Unit costs in China can be greatly reduced by improving project design and management of implementation, including project planning, equipment distribution, construction, operating techniques and procedures, and service and maintenance. Project construction periods must be reduced. Achieving these efficiency improvements requires both good organization and experience. Some lessons can be gained from abroad, while others must be learned firsthand.
- **Efficient use of Comparative Advantages in Manufacturing.** State-of-the-art technology, often from abroad, is critical to achieve low unit costs. At the same time, increasing use of domestically manufactured items where China has a comparative cost advantage can yield further cost savings. A balanced approach to importation and domestic manufacturing of equipment is required to achieve the lowest costs and highest efficiency. Attempts to substitute domestic production for imported items where China does not have comparative cost advantage, running counter to market forces, will increase costs and reduce efficiency, but failure to develop opportunities for domestic supply where China does have potential cost advantages also is inefficient. In some cases, balanced solutions may involve joint-venture production arrangements that include meaningful technology transfer, and increasing domestic content for items where China has a cost advantage, beginning with assembly and moving into manufacturing of certain components.

Lowering Other Barriers to Market Development

Even where costs are competitive with alternatives, use of renewable energy technologies is hampered by a lack of infrastructure to assist the market to work effectively, and a lack of commercial experience in the renewable energy community. The following problems need to be addressed:

- **Institutional Fragmentation.** Much of China's renewable energy project work has been undertaken by small research and design institutes or local government departments, developed under the planned economy and tied to one of several government institutional systems. With problems compounded by the geographic isolation typical of many areas where resources are most abundant, and the wide variety of technologies in the renewable energy arena, it has proven difficult for these numerous small-scale project entities to both make the transition to the market approach and gain sufficient critical mass for commercial operation. Development of commercial companies from this base will require major efforts in networking and organization, making alliances with Chinese commercial/financial establishments or foreign partners, and access to both venture capital and credit.
- **Insufficient Commercial Experience.** Related to the above problem, most renewable energy project entities in China lack experience in commercial operations and delivery systems. Knowledge of market operations and mechanisms is weak. Training and other means of transferring business knowledge is critically needed in financial analysis, marketing, corporate planning, company management, etc.
- **Lack of Awareness of Potential.** Lack of awareness among decisionmakers outside of the renewable energy community of the opportunities for commercial application of renewable energy technologies remains a major constraint to development. This stems from lack of awareness of recent technical advances and existing successful commercialized applications, especially in other countries.
- **Lack of Information Exchange Among Practitioners.** Lack of access to substantive information on recent technical developments; on new program approaches, marketing techniques and financing methods; and on both good and poor development experiences, is a major problem for renewable energy project entities in China. The problems exists for both domestic and international information.
- **Insufficient Access to Advanced Technology.** This problem exists for software (e.g., on project planning, design and implementation) as much as for hardware. It is exacerbated by the fragmentation and isolation of the renewable energy community. Often, issues concerning intellectual property rights also must be overcome for advanced international technology to be made available.
- **Insufficient Assessment of Resources.** While gaps in general information on the scope and development potential of different renewable energy resources, the lack of the detailed, site-specific time series data needed for project site selection and design optimization is most critical. This requires not only data collection, but also assembly, quality control, processing and dissemination.

- **Insufficient Market Regulation.** Problems with poor quality equipment that does not meet user expectations have plagued China's efforts for many technologies, including solar hot water heaters, biogas plants, and solar home systems. Given the lack of suitable consumer-oriented information, there is an urgent need for the Government to assist industry to develop and implement quality specifications and standards, and a certification process. Otherwise, there is a danger that poor performance, misrepresentation and misinformation will undercut dissemination efforts.
- **Underdeveloped Regulatory Framework for Power Sales.** Progress has been made recently in developing a framework for sale of electric power from large independent generators to the power grids. However, further progress, achieved in part through demonstration efforts, remains essential, especially for small producers and for different renewable energy technologies with different load and economic characteristics.
- **Underdeveloped Linkages with the Financial Community and Insufficient Access to Credit.** Renewable energy technologies generally have high capital costs and low operating costs relative to alternative technologies, making access to consumer credit for off-grid systems and long-term commercial credit for grid-connected systems important. Within China, availability of long-term credit from commercial banks remains limited and somewhat controlled, and other sources of long-term financing are still under development. Compounding this problem, potential financiers are generally unaware of successful experience in commercial renewable energy applications, and the Chinese renewable energy community is desperately lacking in financing skills and experience.

Role of International Assistance

Renewable energy must develop within the market framework if it is to make an appreciable difference in China's energy balance and develop efficiently. However, renewable energy development cannot proceed effectively solely based on market forces, without public sector support. Left to market forces alone, renewable energy most definitely will not develop at the speed required to meet environmental objectives, and public sector support is well justified to speed development. However, the demand-based approach does mean that:

- Strong support should be given for the development of the niche markets where applications are economically viable now with technology readily available.
- Public incentives to spur commercialization should be designed to expand demand for targeted renewable energy technologies. Rather than providing direct incentives to technology suppliers to expand production, demand-based incentives should expand

the market for which suppliers compete. Building in some cases upon existing niche applications, demand-based incentives should be designed to result in as great an expansion of demand as possible, stimulating expansion in production and further unit cost reduction.

- Strong emphasis should be placed on the development of market infrastructure to enable the market to work efficiently under both cases above. Some of the priorities include improving information quality and access, improving technology access, improved resource assessment, improved government regulation in certain areas, and training in commercial operations.

Expanded international donor support for China's renewable energy development is particularly important at this juncture, when the Government is beginning to mobilize for a much expanded program and put in place the foundation for development under the market system. The experience of other countries in fostering renewable energy development in market economies, targeting public support to achieve environmental benefits, and making transitions from pilot demonstration to technology commercialization are especially instructive. Assistance from international donor agencies can help to provide access to technical and business knowledge through technical assistance; to facilitate technology transfer through support for demonstration projects and joint ventures; and to assist in reducing costs and addressing market barriers through support for initial investments to kick-start the most promising technologies.

CHAPTER 3. SUPPORTING POLICY AND INSTITUTIONAL CAPACITY DEVELOPMENT

POLICY SUPPORT

International experience shows that government policy support is key to moving renewable energy development forward in initial stages. Successfully meeting the strategic environmental agenda requires effective long-term planning, careful establishment of priorities, and sustained and coordinated programs involving a variety of government and commercial institutions. Although goals may be long term, implementation of action plans over the short term is critical. Success requires not only leadership but increased government and donor financial support. Coordination of efforts and information exchange needs to be further increased so that the combined effect is maximized.

All countries engaged in modern renewable energy development have used and continue to use special financial incentives to encourage the expanded use of renewable energy technologies, such as grid-connected wind power and solar PV, which are not yet financially viable when compared to low cost alternatives such as coal-fired thermal power. Such financial incentives may be justified by the environmental benefits of renewable energy compared with other, polluting energy sources, but incentives policies should be carefully designed to:

- have clear objectives related to the expansion of defined renewable energy markets, improvement in product quality and, especially, cost reduction;
- minimize distortions in market signals, including distortions in the financial market and tax systems, e.g., by concentrating particularly on reducing capital costs or increasing revenues for a finite set of specific and defined projects;
- structure incentives so that they reflect the long-term economic (social) value of the services provided (including environmental values); and
- be as cost effective as possible, in terms of requiring the minimum level of funds for the maximum social benefit. The incentives should apply only for a specified period of time, and results should be closely monitored.

In China's case, the Government is engaged in a review of current financial incentives schemes, and plans to undertake a series of readjustments and improvements to establish a set of schemes which can yield better results. The World Bank is managing a

technical assistance program on Financial Policy for Renewable Energy Development, to assist the Chinese Government in this effort, with financing from the Government of the Netherlands. The program involves a detailed review of lessons learned from about six countries active in renewable energy, following which a multi-institutional Chinese team will prepare recommendations for government implementation.¹

Some additional areas where international assistance may be especially helpful to assist the Government in renewable energy policy development include:

- **Strengthening of China's Long-Term R&D and Technology Transfer Program for Renewable Energy.** For renewable energy to have a significant environmental impact in the long term, major progress must be achieved over the next decade in the development of new technologies. China's current investments in longer-term technology development are woefully inadequate, given the strategic importance to China. Work needs to include sustained scientific R&D, reviews and assessment of international trends, selected acquisition of technology from abroad, and pilot demonstration for new technologies that may not become commercial in the short term, but might have the potential for large-scale application over the longer term (e.g., various new approaches for PVs and PV manufacturing, fuel cell and/or hydrogen production technologies integrated with renewable energy systems, solar-thermal power generation technologies, and new approaches to efficiently and conveniently utilize crop residues in decentralized systems, etc.). China's Government needs to develop and implement a well-planned strategy for a stronger technology development program, including (a) careful selection of priorities, based on continuing assessment of emerging trends; (b) development of the most efficient combination of domestic R&D and foreign technology acquisition for areas of priority focus; (c) major increases in public funding for priority areas; and (d) expanded coordination and partnership development between government agencies, research institutions and industry. International assistance needs especially include (a) advice from senior practitioners involved in similar public-sector programs in other countries on the development and implementation an improved new technology development strategy and program; (b) international scientific and technical advice; and (c) funding assistance for technology acquisition, strengthening of domestic R&D capacity in priority areas, and selected pilot demonstrations.
- **Continued Assessment of Commercialization Priorities.** The recent work by government agencies to support the New and Renewable Energy Development Program, together with the two recently completed Bank/GEF assessments, provides a solid foundation for defining priorities for commercialization. However, these

¹ See The World Bank, *China: Financial Policy for Renewable Energy—Proceedings of an International Workshop, February 1997, Amsterdam, The Netherlands* (forthcoming).

reviews will need to be continually deepened and updated as technology advances and changes in costs of both renewable energy and competing technologies necessitate periodic reassessment.

- **Regulatory Policies.** Two areas of regulatory policy of particular importance today, where China could benefit from advice based on international experience, include: (a) development of a more transparent and simplified framework for setting power sale prices and purchase agreements for small producers selling to power grids; and (b) development, implementation and enforcement of standards, testing and certification programs for certain technologies, to ensure minimum quality and performance levels.

DEVELOPING RENEWABLE ENERGY INSTITUTIONAL CAPACITY

Renewable energy development in China is doubly challenging since the normal barriers to renewable energy deployment are complicated by the economic transition from central planning to the market. At the Central Government level, responsibilities for renewable energy development are split between a number of agencies, including SPC (planning and macroeconomic investment policy), SETC (technology commercialization), SSTC (most R&D), and various line ministries (e.g., the Ministries of Power, Agriculture and Water Resources). Coordination between these groups, however, is fairly effective, as the relatively small number of staff involved have worked together toward a common goal, often for many years. Problems of insufficient coordination, duplication of effort and fragmentation are more apparent among the wide variety of research institutions and government units at provincial and local levels.

Aside from the need to strengthen leadership and effect greater consolidation of efforts in local implementation work, there is an urgent need to develop capabilities to develop and work within the new, more market-oriented approach of the future, both within government and within emerging commercial companies. It will be difficult and slow for China to make the transition to market-based development without further technical assistance in these areas.

Government Capacity

International assistance could help strengthen the Government's capacity to facilitate development of commercial markets for renewable energy by:

- **Increasing Awareness Outside of the Renewable Energy Community.** Awareness of China's energy professionals and government policymakers about the benefits and the potential for commercial development of renewable energy needs to be increased by conducting study tours, workshops and seminars. The simple fact is seeing is believing. Staff of utilities, research institutes and energy companies need to visit and learn from major renewable energy projects and advanced equipment manufacturers

in other countries. National and provincial policymakers need to investigate the policies used in other countries and their impact in creating renewable energy industries.

- **Training of Renewable Energy Staff.** Formal and informal training of government and related staff working in the renewable energy field is needed concerning the role of government policy and regulation in a market economy, financial and economic analysis of projects, and international project implementation and management experiences. Training in project financing is critically needed.
- **Strengthening Renewable Energy Supporting Institutions.** Much of the detailed technical work required by the government for policy development, project selection, and program implementation must be undertaken by supporting research institutions. The capacity of these units also needs to be greatly expanded, especially concerning policy analysis, financial and economic analysis of project, and project and program implementation. One promising development in this regard is the recent establishment of The Center for Renewable Energy Development in Beijing. In addition, there is a need to further develop linkages and institutional partnerships between the renewable energy and financial community.
- **Incorporating Externalities in Cost Comparisons.** The Government needs to further develop methodologies to estimate the value of environmental and societal external costs associated with conventional energy production and use, and work toward incorporating them in benefit/cost comparisons used to evaluate investment alternatives.

Commercial Capability

Development of effective renewable energy corporations and businesses requires major efforts in networking and organization to link existing small entities, making new alliances with Chinese financial establishments or foreign partners, and gaining access to both venture capital and credit. International assistance can help develop these entrepreneurial outward-oriented renewable energy businesses by supporting transfer of international experience and technology through:

- **Internships.** Chinese professionals need to learn on the job by working as interns for lengthy periods in utilities and renewable energy businesses in other countries.
- **Training Programs for Renewable Energy Entrepreneurs.** Chinese renewable energy professionals and entrepreneurs would greatly benefit from workshops, seminars, and training programs given by successful renewable energy entrepreneurs from other countries, focused on developing business skills in areas such as corporate planning, company management, marketing, and project financing.

- **Technology-Specific Workshops.** Workshops are needed to bring together international and Chinese entrepreneurs, staff of investment firms and banks, and renewable energy professionals, to identify business opportunities and opportunities for investments, joint ventures, and technology transfer.

Resource Assessment

Accurate resource data is essential in order to reduce risks to project developers, and reduce costs by enabling optimal site selection and project design. As renewable energy projects tend to be small, individual investors cannot afford extensive investigation. Public support is needed in China to collect, analyze and make available to renewable energy project developers data on alternative sites, including not only time series data on the energy resource, but also logistical factors, and local energy requirements. Resource assessment need to be targeted to those technologies with greatest promise for commercial development at this point, such as wind power and solar PV. International assistance can help to develop resource assessment capacity at national and provincial levels by providing technology transfer and training in:

- **Resource Assessment and Site Selection, Especially for Key Technologies such as Grid-Connected Wind Farms.** This should involve on-the-job training of Chinese analysts to use advanced screening techniques combining global imaging system (GIS) data and remote sensing data to analyze resource adequacy, site access and availability of reliable grid to select prime sites.
- **Wind Resource Data Monitoring on Prime Sites.** Resource availability should be monitored using specialized instruments, and then data should be processed and archived. data processing should include energy calculations and should be publicized. Both equipment and on-the-job training are needed.
- **Preparation of Prefeasibility Studies.** Availability of prefeasibility studies greatly reduces the risks and costs to potential developers.

CHAPTER 4. DEVELOPMENT PROGRAMS FOR PROMISING TECHNOLOGIES

The Government, with international support, plans to carry out step-by-step programs to further develop and commercialize each of a series of promising technologies, aimed at rapidly expanding market penetration. The basic challenges cited previously—to reduce costs and lower other barriers to market development—and strategies to meet them through a market approach represent common themes among most of the cases, although further commercialization of each technology has its own specific requirements and circumstances.

The sections below summarize the findings of detailed assessments organized by the Bank and SETC. Additional detail is available upon request in the Bank's report, "China: Renewable Energy for Power" (September 1996); and a series of reports completed by SETC, entitled "China: Renewable Energy for Thermal Applications" (December 1996).

GRID CONNECTED WIND FARMS

Among nonhydropower renewable energy technologies, wind power projects have the largest short-term potential to contribute to power supply. Although grid-connected wind farm development in China has only begun and site assessment is at an early stage, sites already identified have a potential of 3,000-8,000 MW. Available data indicate that China has world-class wind resources, with a technical potential of 250 GW. The Government gives wind farm development high priority, targeting 400 MW to be installed by 2000.

However, while international turbine manufacturers and wind farm developers have shown interest in the Chinese market, current financial returns on wind farm development are too low to attract large-scale utility or independent power producer (IPP) investment. Despite the government targets and the apparent attractiveness of the sites, there were only 57 MW of demonstration scale grid-connected wind farms in China by the end of 1996, financed mainly through concessional bilateral trade deals.

In most cases, wind power is still not yet financially viable when compared to baseload coal-fired thermal power generation in China. However, wind power clearly can become viable on a growing number of sites in the future, due to a combination of increasing environmental protection requirements for coal-fired power plants, cost reductions in wind generation by achieving greater economies of scale, increases in the

efficiency of wind farm development, and reductions in wind turbine manufacturing costs, in part through increasing domestic content. To achieve this, China must make the transition to true commercial-scale development. Based on experience in other countries, the critical point is to successfully put the first 400-500 MW of world-class wind farms on the power system, providing the necessary but currently missing jump-start for a major wind power development program. The development of the first set of commercial-scale wind farms provides the practical means to undertake the following key steps necessary for large-scale development:

- **Development of Framework for Wind Power Development by IPPs.** Much of the future wind power development will be undertaken by domestic, foreign and joint-venture IPPs. The first projects will need to address outstanding issues concerning wind power pricing and operational interfaces with the purchasing power grids, and lay the foundation for further IPP wind power development.
- **Improving Efficiency.** China's wind power development industry lacks experience in the planning, design, construction and operation of world-class wind farms. Through technology transfer from abroad and the learning by doing associated with implementation of a first set of projects, efficiency can be increased and costs reduced by improved optimization of wind farm design and grid interfaces, shortening of project commissioning periods (which are currently excessively long), improved operational management, etc.
- **Encouragement of Lower-Cost Turbine Manufacturing.** Chinese experts estimate that development of joint-venture manufacturing/assembly of 600 kW wind turbines in China can reduce turbine costs by some 20 percent, by combining advanced international technology with lower-cost local assembly or production of certain components. However, this requires a sustained increase in turbine demand in China, corresponding to wind farm development on a world-class scale.

Specific and targeted public support is required for the first set of wind power projects to become reality, as has been the case in all countries active in wind power development. The government has allocated concessional credit financing for development of about 100 MW of commercial-scale wind farms over the Ninth Five-Year Plan, but international assistance is necessary to help catalyze the additional development necessary for the first commercial demonstrations to be successful. International private companies are expected to play a major role, but international donor assistance, for both technical assistance and investment financing, also is required for the overall package to be realized. SETC and the Ministry of Electric Power have identified a series of prospective project sites and undertaken preliminary feasibility work.

In addition to support for the development of initial large-scale wind farms, two priority areas for intentional donor assistance are needed for free-standing technical

assistance include: (a) enhancement of China's capacity to undertake wind resource assessments; prospective wind site evaluation, monitoring and prioritization; and publication of such data and analytical results; and (b) increasing the capacity of Chinese power utility staff, especially in provincial power companies, to integrate wind power into power system planning and operating practices.

SOLAR PHOTOVOLTAICS

Solar PV technologies are one of the most promising areas for large-scale renewable energy development over the long term. Currently, high unit costs prohibit widespread develop, and limit commercially oriented application to special niches. PV costs continue to decline internationally, however, and are expected to further decline with further advancement in technology and achievement of greater economies of scale through true mass production. The challenge internationally, as well as in China, is to foster further technological advancement and scale economies in PV production by fostering increases in PV demand, through development of those applications at or closest to commercial viability as much as possible. Cost reductions achieved through increases in the scale of development then allow market expansion, further fostering cost reduction in production. In the near term, development of niche markets for decentralized power in remote areas can provide needed markets to build the PV industry further, providing opportunities to invest in new, larger-scale facilities, producing at lower unit cost. Over the medium term, PVs can then be expected to become increasingly commercially viable for an increasingly wider range of applications, including centralized PV stations, grid support and peak-shaving in commercial and residential buildings. In the near term, top priorities should be given to development of the more isolated niche markets, combined with step-by-step implementation of a more long-term strategy to acquire, develop and expand advanced PV production technology.

Solar PVs have excellent near term commercial potential for supplying power to isolated users in northwest China, where solar radiation is excellent, temperatures are low, population density is low, and seminomadic populations live in rugged terrain with limited transport facilities. Solar PV can provide cost-effective small power to households and commercial activities in remote areas, improving living and working conditions and providing service well above that from kerosene/butter lamps and dry-cell batteries.

The PV market is only beginning to develop in China, with installed capacity estimated at 3 megawatts-peak (MW_p) in 1994, of which 1 MW was for household use. PV module production capacity in China was estimated at 5 MW_p, although sales in 1994 were only about 1.4 MW_p. Production is inefficient, on a small scale and using outdated technology.

While the solar home systems (SHS) business is only beginning in China, SHS sales are growing fast, aided by subsidies provided by provincial governments. Growth of the SHS market, however, is hampered by the following barriers: (a) inefficient, small-scale production of key system components; (b) limited competition, since subsidies are given only to state-sponsored suppliers; (c) poor quality of products that do not meet internationally accepted standards for modules, components and systems; (d) limited credit available to PV system suppliers or system purchasers; (e) poor service and after-sales support facilities offered by suppliers; and (f) a low level of government support for R&D on solar photovoltaic energy, divided among several research centers.

The Government strongly supports use of SHS and centralized PV systems to provide power in remote areas of the northwest and coastal regions, as part of its Renewable Energy Development Program. Studies show a large potential market, indicating that a 12 MW investment program could serve 500,000 homes in the northwest provinces, about 25 percent of unelectrified households. A series of pilot projects already have been identified by the Government. This would triple the size of PV markets from the 1994 level, increasing the potential for investment in modern, low-cost PV technology. However, a large-scale market-based program for solar home and PV systems requires dynamic local businesses that can actively develop, sell and support the systems. The establishment of joint ventures with foreign firms who have established operational experience as well as technology has particular potential in this area, in addition to the PV manufacturing industry itself. In addition, a larger scale SHS program will require that institutional mechanisms be developed for financing and paying for the systems.

Major areas where international agencies can assist the development of the SHS/PV industry in China's northwestern provinces (Inner Mongolia, Qinghai, Tibet, Xinjiang, Gansu) include:

- business development support for SHS and other off-grid PV system suppliers, including: market research to identify energy services required by customers and their willingness to pay; technical assistance for business development and establishment of joint ventures; and financing of working capital and expansion;
- expanding concessional financing support for suppliers of off-grid PV systems during initial stages of developing sales and service networks, when sales volumes are small and dispersed;
- developing channels for making SHS affordable, including providing commercial consumer credit for SHS;
- developing institutional mechanisms required to finance and organize centralized PV systems, including the involvement of local power utilities;

- establishing product specifications and a national quality certification agency, to test and qualify products; and
- establishing a PV industry development strategy, to increase efficiency and lower costs.

SOLAR HOT WATER HEATING

China already has the largest solar hot water heating industry in the world, with 1992 sales representing over 50 percent of the world market. Buyers are mainly urban and township households, but the rural household market is expected to expand sharply as incomes continue to rise.

China's solar hot water heating industry, however, is not sufficiently well placed to meet growing demand, as current capacity is insufficient to meet demand, especially for high-quality, vacuum-tube systems. The industry is fragmented, with small production lines using outdated equipment. There are problems of poor product quality and inadequate system design, installation and service support. Larger-scale commercial and industrial applications of solar water heaters still need to be explored in China.

While the long-term outlook for the solar heating industry in China is promising, the industry needs to gear up for larger-scale commercial operation, through adoption of new technologies and modern business practices. The Government and international agencies can help to create a dynamic solar hot water industry by providing:

- improved access to long-term commercial credit to enable suppliers to make new investments and upgrade existing facilities;
- business development assistance to equipment suppliers for market research, business planning, product development, marketing and development of adequate sales and service;
- help to develop standards and certification procedures to ensure that consumers receive high quality products;
- design and demonstration of large-scale solar water heating facilities for institutional and commercial customers.

BAGASSE COGENERATION

About 700-900 MW of cost-effective renewable energy generating capacity can be added to power grid supply in Guangdong, Yunnan and Guangxi Provinces if surplus power capacity for grid supply is installed as part of the ongoing rapid sugar mill expansion. Investment in surplus power generation is attractive today, on both an

economic and financial basis, with an economic internal rate of return conservatively estimated at 33 percent and financial internal rate of return at 20 percent.

However, this potential will not be realized without government and international assistance. While surplus power production from sugar mills is routinely practiced worldwide, it is not practiced in China, where bagasse cogeneration is used only to supply in-mill power needs (over 800 MW installed in Guangdong and Guangxi alone). As the technology and operating practices for surplus power generation are somewhat different than current ones, demonstration of surplus generation is needed based on international experience. Also, as noted for wind farms, a standard IPP framework for private power sales to the grid is not in place. Finally, credit for mill expansion is limited to the amounts required for in-mill power generation, and is available only on a three-year term.

Since expansion of sugar mills is already under way, action is urgently needed or opportunities will be forgone. Assistance from international agencies could help China realize the potential for surplus power from bagasse cogeneration by supporting:

- technical demonstration of the technology in at least one mill and promotion of the technology, operating practices, and power sales arrangements among mill owners;
- study of grid integration issues with Ministry of Water Resources, and preparation of a standardized power purchase agreement and tariff designed specifically for bagasse cogeneration projects; and
- provision to mills of long-term credit for investment in surplus power facilities, on commercial terms.

Biomass Gasification for Heat

While biomass resources are widely used already in rural areas of China, efficient use of biomass wastes for gasification is in early stages of development. If gasification can be done successfully, there are huge markets in providing (a) gas to households for cooking and heating; (b) clean fuel for township and village enterprises and small commercial activity; and (c) clean, high-quality heat for drying, processing crops, etc.

China has substantial existing, but scattered, capacity on biomass gasification, with several research centers developing gasifiers for different market niches including: forest and wood industries; rice industries; and use of straws and stalks at the village level. Two factories are producing gasifiers at a rate of 150 units each per year. The most successful application is the ND-600 wood-fueled gasifier, with 600 units in operation and 150 units produced per year. However, while the potential market is significant, development has not begun at a commercial level, and gasifiers are still being produced

and sold solely by research institutes that do not have the commercial infrastructure or the business know-how required to expand sales and service to a large market.

The Government, assisted by international agencies, needs to carry out the following step-by-step development program:

- complete a rigorous and critical assessment of the experience to date in China, with feedstocks, gasifiers and uses, in the light of international experience. Market research is then needed on the most promising feedstocks and applications;
- where the potential is significant and technologies are ready, commercial companies need to be formed to market and support gasifiers. These companies will need technical assistance in business planning and market development;
- for those gasifiers with commercial potential that require further development, support for R&D activities and international technology transfer are needed;
- in the initial stages of establishing businesses, limited and targeted financial incentives may be needed to overcome barriers to market expansion;
- improved access to credit may be needed for suppliers of gasifiers to expand their manufacturing capacity and sales and service networks.

BIOGAS FOR POWER/EFFLUENT TREATMENT

China is a world leader in the application of anaerobic fermentation technologies. In addition to millions of household-sized units, there are about 150 units now operating on industrial wastewater. Use of anaerobic digestion for energy not only produces economic benefits, but reduces local water and groundwater pollution by 70-90 percent and reduces GHG emissions. If 50 percent of all industrial wastewater was treated this way, the volume of biogas produced would equal current natural gas production in China. Industries that could use anaerobic digestion include pulp and paper, sugar processing, fermentation alcohol production, pharmaceutical and food production.

Only a small share of waste water is now treated, e.g., 10 percent of distilleries have treatment. While investment in anaerobic digestion is often economically viable, distillery owners find it more profitable to invest in expansion of their production facilities. However, 20 percent of distilleries are facing provincial and municipal imposed regulatory deadlines to correct their emissions or go out of business. This group alone represents about 600,000 tons of alcohol production and requires an investment in anaerobic digestion of about 300 million yuan to offset the use of about 210,000 tons of coal per year.

Increased use of anaerobic digestion in distilleries and other industrial plants is a priority for environmental reasons. Areas where assistance is needed include programs to:

- review and strengthen the policies and regulatory pollution control frameworks and enforcement mechanisms;
- promote the benefits of reduced water pollution as a result of anaerobic digestion among environmental agencies, advocates and industry owners;
- assist technology transfer is needed from countries that have more experience with these technologies;
- establish companies to design, install and service such facilities;
- facilitate access to long-term credit is required on commercial terms.

GEOTHERMAL ENERGY FOR HEAT

China is a global leader in geothermal direct heating applications, with 24 percent of the world's installed capacity. However, this has only begun to tap the potential. Low and medium temperature resources are mainly located in the inland and coastal areas where population densities are high, and where the demand for space and water heating is growing. Most of the geothermal development for these applications to date has been carried out by the Tianjin Geothermal Center, which lacks the commercial experience and financial resources to develop potential markets, and to identify economically and financially viable projects. There are technical limitations as well, including limitations on wellhead equipment design, and installation and operation of facilities, which are weak areas in current facilities.

Needs for further development involve:

- carrying out a number of prefeasibility studies for specific sites and applications, including resource investigation, definition of potential markets and economic and financial viability;
- development of a commercial infrastructure for designing, installing and servicing geothermal facilities for financially viable cases. Companies need to be set up and assisted with business development plans and startup capital.

GEOTHERMAL ENERGY FOR POWER

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 Yangbajing, Tibet. High temperature resources (i.e., >100°C) exist in 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.

The technically and economically feasible electric potential of all geothermal resources in Tibet and western Yunnan Province may be 200 to 500 MW. As a first step toward realizing this potential within the next 10 to 20 years, the Government would like to carry out the following program, with assistance from international agencies:

- reexamine the economic potential of all major hot-spring occurrences for power generation, taking into account both resource potential and demand for power;
- develop a strategy for efficient implementation of projects with capacities of 1-2 MW, which require special attention 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. Promising sites, such as the Rehai field in Yunnan, desire priority attention.

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