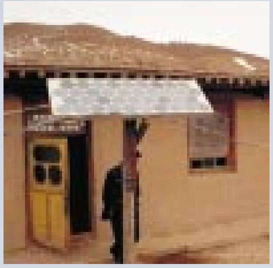


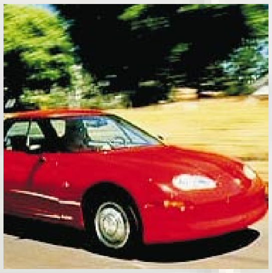


Protocol for Cooperation in the Fields of

Energy Efficiency and Renewable Energy

Progress Report

中美能源效率及
可再生能源领域合作议定书
进展报告

Between the Department of Energy of the United States and the Ministry of Science and Technology of the People's Republic of China

中华人民共和国科技部
与　美国能源部

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List of Abbreviations

Technical

Measures and Units

GW	Gigawatt, 1,000 megawatts of electric power (Subscript this used to describe thermal power)
kW	Kilowatt, 1,000 watts of electric power
kWh	Kilowatt-hour, unit of electric energy
Mtce	Million Tons of Coal Equivalent, equal to 0.12276 TWh of electricity
MW	Megawatt, 1,000 kilowatts of electric power
RMB	Renminbi, domestic currency = 1 yuan used for foreign exchange
TW	Terawatt, 1,000 gigawatts
Wp	Watts-Peak, Maximum output from a solar photovoltaic panel or other device with variable output
Yuan	Unit of China money, United States $1= 8.27 Yuan

Terminology

BOD	Biological Oxygen Demand in water
COD	Chemical Oxygen Demand in water
GIS	Global Information System; digital data base on terrain and manmade surface features
PV	Photovoltaic, solid state device that converts solar energy to electricity

China Organizations

MOST	Ministry of Science and Technology
SDPC	State Development and Planning Commission
SETC	State Economic and Trade Commission
SPCC	State Power Corporation of China

United States Organizations

DOE	U.S. Department of Energy
NREL	National Renewable Energy Laboratory

技术术语缩写

量度单位

GW	相当于 100 万千瓦电功率（下标 $_{th}$表示火电）
kW	千瓦,相当于 1,000 瓦电功率
kWh	千瓦时，电能的单位
Mtce	一百万吨标准煤，等于 0.12276 TWh 电能
MW	兆瓦，相当于 1,000 千瓦电功率
RMB	人民币,国内货币
TW	太瓦，相当于 10 亿千瓦电力功率
Wp	峰瓦，太阳能光电板或其它有变化输出功率装置的最大输出功率
Yuan	中国货币的单位，1 美元= 8.27 元

术语

BOD	水中的生物耗氧基
COD	水中的化学耗氧基
GIS	地理信息系统；数字地形数据与手绘地表特征图相结合
PV	光伏，将太阳能转变成电能的固定装置

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Scott Vaupen — 美国风能协会和可再生能源专家委员会

The first U.S./China Energy Efficiency and Renewable Energy Protocol Working Group Meeting was held at the Department of Energy in Washington, DC, on November 4-5, 1998.

Delegates:

4th Row – Li Junfeng, Chris Sherring, Ralph Overend, Bo Shen

3rd Row – Daniel Ancona, William Wallace, Dave Renne, Robert Hassett, Dennis Elliott, John Byrne, Wang Sicheng

2nd Row – Ju Qi, Chen Futao, Li Xiuguo, Li Jingming, Shi Yingyi, Xu Jing, Peter Tu, Lin Li

1st Row – Zhu Junsheng, Peter Paul Jodoin, Shi Dinghuan, Allan Hoffman, Lee Gebert, Peter Salmon-Cox, Yin Lian

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Executive Summary

This report, prepared jointly by the United States Department of Energy (DOE), and the People's Republic of China, Ministry of Science and Technology (formerly the State Science & Technology Commission (SSTC)), documents progress that has been made by both countries in areas covered by the Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Technology Development and Utilization (hereinafter referred to as Protocol). The report focuses on the first three years of work done under the Protocol which was reviewed at the first Joint Working Group Meeting held in Washington, D.C., on November 4-5, 1998. Additional information on activities subsequent to that meeting is included where possible.

China's Energy and Environment Challenges

China is currently the world's second largest energy consumer, after the United States (about 35 quadrillion Btu in China in 1995, versus 88 quadrillion Btu in the U.S.). China is also the world's largest coal producer and consumer. Electricity generation is dominated by coal-fired plants (about 75 percent in China in 1995 versus 51 percent in the U.S.). Heavy reliance on coal has caused severe environmental pollution in China including acid rain, smog, toxic waste, water pollution, and carbon dioxide emissions. China now accounts for about 13 percent of world's carbon emissions, ranking second behind the U.S. As China's economic growth of the past two decades continues, demand for energy is expected to increase at a rate of 4-5 percent annually through 2015. At this rate, China could surpass the U.S. as the world's largest energy consumer and greenhouse gas emitter by the year 2025, according to the U.S. Department of Energy's, Energy Information Administration.

China recognizes these challenges and the need to pursue aggressive programs to support environmental and social concerns while maintaining economic and energy development. Key programs include deployment of energy efficient and renewable energy technologies to reduce reliance on coal and providing energy to the estimated 60 million habitants who live in remote, rural areas and islands which lack access to an electricity grid. China's Agenda 21 Program was developed following the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992. The program plan emphasizes use of energy efficiency, renewable energy, clean coal technology, combined cycle power plants, and nuclear power. In March 1994, China's State Council approved the Sustainable Energy Programs under Agenda 21.

Subsequently, in the Ninth Five-Year Plan (1996-2000), China adopted several ambitious national programs including the "Brightness Program," "Integrated and Comprehensive Rural Electrification," "Energy Efficient Lighting," and "Riding the Wind Program." In addition, China is implementing the Energy Conservation Law, adopted by the People's Congress on November 1, 1997. All of those programs and policies aim to use efficiency and renewable energy as a means of reducing energy intensity (the energy used to produce a unit of Gross Domestic Product) and providing least-cost electricity to remote areas, thus curtailing environmental damage.

U.S.-China Energy Efficiency and Renewable Energy Protocol

In response to an invitation from Dr. Song Jiang, Chairman of the SSTC and of China's National Climate Committee, U.S. Secretary of Energy, Hazel O'Leary led a Presidential Mission on Sustainable Energy and Trade to China in February 1995. During that visit seven new agreements were signed including the Energy Efficiency and Renewable Energy Protocol.

The Protocol focuses on three sustainable energy goals: (1) to advance world energy security interests by helping China develop more diversified energy resources and thereby reduce its future demand for oil; (2) to mitigate environmental damage associated with rapid growth in energy demand through deployment of renewable energy and energy efficiency measures; and (3) to enhance U.S. industry competitiveness in China's energy market.

Activities under this Protocol also support goals of the U.S.-China Forum on Environment and Development discussed at the second meeting of the Forum, which was co-chaired by U.S. Vice President Al Gore and Chinese Premier Zhu Rongji on April 9, 1999, in Washington, D.C. The Forum includes an Energy Policy Working Group that is co-chaired by the DOE and the SDPC, covering many facets of various agreements in areas including: renewable energy, energy efficiency, oil and gas, clean coal technology, coal mine methane, and other topics.

The first meetings of the Forum on Environment and Development and its Working Groups were in March 1997 in Beijing. Building on successful initial discussions in the areas of energy and environment, in October 1997, then Secretary of Energy Federico Peña and SDPC Minister Zeng Peiyan co-signed a joint statement, the "Energy and Environment Cooperation Initiative." The Initiative is aimed at strengthening bilateral cooperation with a view toward helping China meet its energy needs in a way which advances local, regional and global environmental concerns, including global climate change. The Initiative also identified three areas as priority areas for cooperation: urban air quality; clean energy and energy efficiency; and rural electrification.

The Protocol advances the goals of the U.S.-China Forum and the Energy and Environment Cooperation Initiative by promoting energy efficiency and renewable energy and specifically by advancing these applications to help meet China's rural electrification and environmental goals. Cooperation under the Protocol may include: technical assistance, training, policy analysis, resource and market assessment, and information exchange. The Protocol now has six annexes, four of which relate to renewable energy, one to energy efficiency, and one to electric and hybrid-electric vehicles.

Status of the Protocol and Accomplishments

Annex I, Rural Energy Development – signed with the Ministry of Agriculture (MOA) on June 27, 1995, focuses on the use of village scale renewable technologies such as biogasification, wind, solar photovoltaics, and wind/solar hybrid systems to provide energy or electricity to China's rural areas. Cooperative activities include pilot projects for rural electrification, training and personnel exchanges, and a U.S.-China Rural Electrification Workshop. Three successful projects, which can be replicated in other areas of China, have laid a solid foundation for China's rural energy development.

- **Gansu Solar Home System Project** – The U.S. Solar Electric Light Fund (SELF) and the Gansu Solar Electric Light Fund (GSELF), supported by DOE's National Renewable Energy Laboratory (NREL) and MOA, completed installation of 320 photovoltaic (PV) solar home systems in 1998. In addition, ten schools were equipped with U.S. made, 53-watt PV systems. As a direct result of Protocol projects, another 275 systems have been installed by GSELF with support of the Gansu Provincial government. This success led the MOA to expand its solar home system project to

10,000 households in six northwestern provinces. A market characterization survey, analyzing social and economic factors which impact the sustainable development of PV technology, is currently being conducted in Qinghai and Xingjiang provinces.

- **Rural Biomass Collaboration** – DOE/NREL collaborated with MOA to develop an assessment of biomass resources, a description of China's technological capability in some of the biomass conversion areas, and an initial techno-economic assessment of potentially useful biomass and bioenergy systems. Reports on this initial data and research were published in China as a bilingual set of three books titled: (1) "Assessment of Biomass Resource Availability," (2) "Biomass Energy Conversion Technologies in China," and (3) "Design for Market-Oriented Development Strategy of Bioenergy Technologies," and as a CD-ROM.

- **Inner Mongolia Hybrid Household Project** – The University of Delaware and DOE/NREL completed case studies on household and village power systems, including technical performance and economic analyses of 41 households and three villages in 1997. Subsequently, in a pilot project between DOE/NREL and the Inner Mongolia New Energy Office, 96 household PV/wind (450-500 watt) systems were installed initially, with an additional 125 systems installed in 1999, and 120 in the year 2000. The U.S. is providing U.S. PV modules for this project. As a result of this activity, local officials in Dongwu County have completed a feasibility study and plan for 4,000 hybrid systems to be installed over the next five years.

Annex II, Wind Energy Development in China – signed with the Ministry of Electric Power (now SPCC) on October 25, 1996, focuses on accelerating sustainable large-scale development of wind power in both grid-connected and off-grid village power applications in China. With support from DOE, NREL, and the U.S. wind industry, the objectives of this annex are to demonstrate the technical and economic feasibility of advanced wind energy technology and to enhance its commercialization potential for the benefit of both countries. Cooperative activities include resource assessment, utility wind power plant analysis, a finance workshop, wind/hybrid mini-grid analysis, project development and personnel exchanges in training programs. Major projects include:

- **Wind Resource Assessment and Mapping** – The DOE/NREL, in partnership with the U.S. Environmental Protection Agency (EPA), completed a southeast China wind resource assessment and mapping in 1998 in the provinces of Jiangxi, Fujian, and the eastern half of Guangdong. The mapping products are designed in highlight areas that are expected to have a favorable wind resource and where specific wind energy projects are likely to be feasible. The most attractive wind resource is found along the coastal area and on the offshore islands, particularly along the coast of Fujian, where many excellent sites were identified by the mapping process. Verification of wind resource estimates is continuing, using local electric power bureaus' data and digital data collected from nine anemometers supplied by the U.S.

- **Xiao Qing Dao Village Power Project** – DOE/NREL and SPCC are currently developing a pilot project using a wind/diesel/battery system to electrify 120 households on an island called Xiao Qing Dao located in the Yellow Sea off Shandong Province. The DOE will provide four 7-kW wind turbines, batteries, a 40-kW inverter, and spare parts. The SPCC will provide the diesel generator, the turbine towers, foundations, buildings, and the distribution systems. In addition, the SPCC will collect performance and operational data for DOE/NREL and the project is estimated to be commissioned in 2000.

Annex III, Energy Efficiency – signed with the State Planning Commission (now SDPC) on October 25, 1996, focuses on ten areas: (1) energy policy; (2) information exchange and business outreach; (3) district heating; (4) cogeneration; (5) buildings; (6) motor systems; (7) industrial process control; (8) lighting; (9) amorphous core transformers; and (10) finance. Both sides established 10 teams composed of representatives from industry, government agencies, and energy association to address barriers and opportunities. An Energy Efficiency Steering Committee Meeting, co-chaired by DOE and SDPC, was held in 1997 to evaluate progress made in the past and to discuss future plans. Major activities include:

- **Electric Motor Systems** – A DOE delegation conducted a Motor Challenge workshop on electric systems in Beijing in May 1998, and a second workshop on pumping systems was held in November 1999. The SDPC plans to make this a national program in China.

- **Energy Efficiency Policy** – China is currently implementing its Energy Conservation Law that was signed on November 1, 1997. At China's request, U.S. experts discussed implementation of U.S. energy efficiency laws, policies, and standards, at a workshop in Beijing in December 1997.

- **Energy Efficient Buildings** – An action plan for cooperation on energy efficient buildings has been prepared.

Subsequently, a second Energy Efficiency Meeting was held in June 1999 in Beijing. The results of that meeting were not available in time to be included in this report.

Annex IV, Renewable Energy Business Development – signed with the State Economic and Trade Commission (SETC) on October 25, 1996, is implemented by the Center for Renewable Energy Development (CRED), an organization under China's SDPC. This Annex focuses on renewable energy policy analysis and development, information exchange, business outreach, training, and project finance. Activities include:

- **Provincial Renewable Business Profiles** – Two business development studies have been performed in partnership between CRED and NREL. The first study conducted in late 1996, described factors that influence the deployment of renewable energy in six provinces (Gansu, Inner Mongolia, Qinghai, Shangdon, Xinjiang, and Zhejiang). The second study conducted in 1998, included four additional provinces (Guangdong, Jiangxi, Jilin and Yunnan) and discussed changes that have been made under China's government restructuring.

- **Chinese PV Industry and Technology Assessments** – An evaluation of local PV businesses and applications was conducted in 1998 and will be published in early 2000. This evaluation includes local interviews with a large number of PV cell and module manufacturers, distributors, and integrators. A review of the status of PV technology and industry development in China was conducted by CRED and U.S. consultants.

Annex V, Electric and Hybrid-Electric Vehicle Development – signed with the Ministry of Science and Technology (MOST) on November 18, 1997, is to promote cooperative activities on information exchange; economic, environmental, and policy studies; and training.

- **Information Exchange** – Two major collaborative visits occurred in 1997 and 1998. Both sides have agreed that information exchange will be the top priority for the Phase I cooperation. Thus far, many publications and materials regarding electric vehicle infrastructure requirements such as building codes and safety standards have been sent to the MOST. In 1999, a web site is planned to disseminate additional information about electric and hybrid-electric vehicles.

Annex VI, Geothermal Production and Use – signed with the Ministry of Science and Technology (MOST) on November 18, 1997, outlines cooperation in the areas of geothermal electricity generation technologies, geothermal direct use, and geothermal heat pump infrastructure development.

- **Geothermal Drilling Assistance** – DOE provided technical assistance in the areas of drilling technologies and a geophysical survey, to the Tengchong Geothermal Project in Yunnan Province in September 1998, where China intends to build a 10-MW demonstration geothermal power plant.

- **Geothermal Heat Pump Project** – China has proposed using geothermal heat pump (GHP) technology for three demonstration sites (Daqing, Shanghai, and Guangzhou) in three commercial buildings totaling 3.4 million square feet. DOE has agreed to provide technical assistance in feasibility studies and training in exchange for China's commitments to purchase U.S.-made equipment for the project. A comprehensive feasibility study using GHP systems in three temperature zones in China was completed in August 1999.

Conclusion

The United States and China are the two largest energy consumers in the world, and have mutual interests to develop bilateral cooperation, which can build a partnership in achieving common energy security, environmental, and economic goals. Much progress has been made in developing the Protocol Agreement into a framework for cooperation and in the research and development work aimed at accelerating the introduction of renewable energy and efficiency technologies in China. Six technical annex agreements have been developed and are underway. Through these agreements, there have been numerous valuable information exchange visits involving government and industrial firms from both countries. More than 30 U.S. companies are discussing or actively developing business activities with counterpart organizations in China. Pilot projects involving solar, wind, and geothermal energy; electric vehicles; and efficiency technologies are being deployed or planned, either directly under the Protocol Agreement or indirectly as a result of contacts or technical assistance. One joint venture agreement has been signed and other commercial ventures are being developed that should lead to increased economic cooperation and trade. The results of the Protocol activities will lead to reduction of greenhouse gas emissions; opening new, clean, and sustainable energy sources; improve energy efficiency; support rural electrification; and will encourage mutually beneficial business development.

1.0

Introduction and Background

On February 25, 1995, the United States Department of Energy (DOE) and the State Science and Technology Commission, now the Ministry of Science and Technology (MOST), of the People's Republic of China, signed a Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Development and Utilization. Since then, cooperative activities have been defined with other Chinese government agencies, and six specific Annexes to the Protocol have been developed and are now operating.

The Protocol grew out of a strong concern in both countries about environmental and sustainability issues which result from increasing energy demand worldwide and in China specifically. Bilateral scientific and technological cooperation should encourage clean energy use and support sustainable development, resulting in mutual benefits to both countries in increased trade and economic development and energy security.

Results from the Protocol are benefitting both countries. Information is being exchanged for new and advanced technologies involving solar, wind, biomass, energy efficiency, transportation, and geothermal technologies. For selected technologies, mutually beneficial technology exchange is resulting in the deployment of pilot projects in China. These efforts support the goals of using clean energy and sustainable development. More than 30 industrial firms in United States and an equivalent number in China are involved in Protocol activities, resulting in good prospects for new business development and joint ventures. Since the program began in 1995, both countries have spent approximately $2 million USD, and are already achieving environmental benefits and business development results.

This report represents the first progress report on work underway in the areas of renewable energy and energy efficiency under the Protocol Agreement. Specific topics discussed in the report include activities planned, underway, and completed in the following areas: Annex I on Rural Energy Development, Annex II on Wind Energy Development, Annex III on Energy Efficiency, Annex IV on Renewable Energy Business Development, Annex V on Electric Vehicle and Hybrid-electric Vehicle Development, and Annex VI on Geothermal Energy Production and Use.

In October 1997, in conjunction with the first Summit meeting between President William Clinton and President Jiang Zemin, then U.S. Secretary of Energy, Federico Peña and Zeng Peiyan, Executive Vice-Chairman of China's SDPC, signed a joint statement called the "Energy and Environment Cooperation Initiative." The joint statement supports the goals of the U.S.-China Forum on Environment and Development, co-chaired by Vice President Al Gore and Premier Zhu Rongji, in advancing environmentally sound responses to help meet China's energy needs in a way which addresses local, regional and global environmental concerns, including climate change. The goals of the five-year Initiative are to strengthen bilateral cooperation and advance the role of the private sector in China's energy development through enhancing technical cooperation, to promote reforms and improvements in energy policy and investment climate, and to encourage private sector investments. The Initiative is implemented through established protocols and agreements, including the Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy. Priorities for cooperation identified in the Initiative are: urban air quality, clean energy sources, energy efficiency, and rural electrification.

Energy and environmental issues were again discussed during the visit of President William Clinton to China in late June 1998. President Clinton pointed to the importance of this area in a speech on the environment presented during his visit to Guilin, China on 2 July 1998. He said, "In October at our summit, President Jiang and I oversaw the beginning of a joint initiative on clean energy. This week we have made important new progress. We will provide China assistance to monitor air quality. We will increase our support for programs that support renewable energy sources to decrease China's dependence on coal."

As a result of those discussions and meetings with various Chinese government agencies, the DOE agreed to continue support for the Protocol and for renewable energy bilateral cooperation during the 1998 and 1999 Fiscal Years. Work under the six Annexes to the Energy Efficiency and Renewable Energy Agreement includes training, workshops, and business development activities for wind, solar, biomass, geothermal, electric vehicles, rural electrification, and energy efficiency. Details on these programs are discussed in this Report.

The first Protocol Working Group Meeting was held in Washington, D.C., on November 4-5, 1998. This meeting was co-chaired by Shi Dinghuan from the Chinese Ministry of Science and Technology and Allan Hoffman from the U.S. Department of Energy. In his welcoming address, Brian Castelli from the DOE, Office of the Assistant Secretary for Energy Efficiency and Renewable Energy, noted that this was the first meeting of a joint working group between the two governments aimed at developing new energy sources that are both environmentally beneficial and supportive of sustainable development objectives for energy use. The meeting reviewed progress under the Protocol and laid out plans for the future. See Figure 1. The Chinese delegation also visited several industrial renewable energy project sites in California.

Figure 1. U.S. DOE and Commercial Renewable Energy Project Sites in China

2.0

Why China is Interested in Renewable Energy and Efficiency Technologies

China has abundant renewable energy resources and is aware of its environmental problems and energy supply issues. China's energy conservation efforts began in the early 1980s, mainly to address energy shortages throughout the country. In 1990, the National Climate Coordinating Group was created to study policy issues and interagency coordination. Subsequently, China's Agenda 21 Program [Reference 1] was created, defining a strategy to lead China on a sustainable development path in the 21st century. Significant progress has been made on the Agenda 21 Program, which helped with work under the US-China Protocol.

In China's Agenda 21 Program, Chapter 13 was on "Sustainable Energy Production and Consumption" and included sections on both developing renewable energy resources and improving the efficiency of energy use. The part of the Program on the development of new and renewable energy included a detailed estimate of available resources, specific development objectives, and activities needed to achieve them. Following are examples of renewable energy sources and use [1 and 2]:

- In 1993, biomass resources, in the form of crop residues, firewood, and other kinds of organic wastes, supplied about 260 million tons of coal equivalent (Mtce). In rural areas, these fuels supply 44 percent of the overall energy consumption and 69 percent of the energy used in rural households. Bioenergy potential, in the forms of solid, gaseous, and liquid fuels, is largely unused, especially in the agronomous regions in the eastern and southern provinces.

- Wind power resources are estimated to be 1,600 GW, about 10 percent of which is exploitable; at the end of 1998, 223 MW of wind power plants were operating in China. The best wind sites are in northern provinces and in coastal areas.

- Geothermal energy resource potential is yet to be fully explored; known reserves are equivalent to 3,000 Mtce and about 0.3 Mtce is currently developed and in use.

- The best solar resources are widely distributed over more than six million square kilometers, especially in the northern and western provinces and some coastal areas in south China. Many sites have annual sunshine over 600 kilojoules per square centimeter ($kJ/cm^2/yr$). This is comparable to the best solar sites in the U.S.

In 1995, there was increasing concern about the environment and there were many separate groups and agencies developing new and renewable energy technologies, under the Sixth Five-Year Plan. These R&D efforts were summarized by the Chongqing branch of the Institute of Scientific Information of China, with data from MOA, SETC and SSTC. This information was published in a book [2] that was widely distributed in and outside China and served as the basis for work done under subsequent Five Year Plans.

Agenda 21 also focused attention on improving energy efficiency and conservation. These efforts have lead to big improvements in energy efficiency. Energy intensity, measured by primary commercial energy consumption per unit of GDP, has dropped 50 percent since 1980, or 4.5 percent per year. However, China's energy intensity is still three times higher than the U.S. [3] and further improvements in efficiency are urgently needed.

China's primary energy demand has doubled since 1980, with the energy consumption shifting toward electricity and gaseous fuels. Except for the recent downturn, China has been experiencing major economic expansion, similar to the general and rapid economic growth occurring throughout the Pacific Rim countries of Asia. Growth in China's GDP between 1980 and 1990 averaged 9.5 percent. GDP growth peaked in 1992 and 1993 at 13 percent per year, with growth in the industrial sector of some selected "special economic zones" in southern China more than 20 percent per year. More recently, growth has moderated. In 1998, China's real GDP grew 7.8 percent, which is consistent with the government goal of 8 percent annual growth projected to continue through 2015. China's restraint on economic expansion has been effective in controlling inflation, which was estimated to be 5 percent in 1997, -0.9 percent in 1998, and 2.5 percent in 1999. Both controlling inflation and significant GDP growth are expected to continue to be government policy goals for the foreseeable future [4 and 5].

Economic expansion results in many stresses and strains on the Chinese government and industrial infrastructure. Until recently, energy related challenges included: increased demand for electricity and lagging power plant and electricity grid system construction; need for coal, gas, or other energy sources and the means to mine, transport, and process these fuels; increased fuel consumption and the resulting air and water pollution; and unprecedented need for venture capital and commercial financing balanced by concerns about financial stability and balance of trade. Currently, China's electric power industry is experiencing an oversupply situation, due in part to slower economic growth as a result of Asian economic problems and to over building power plants in some areas. Renewable energy development and energy efficiency affect some of these issues in ways that are discussed below.

Concurrent with economic expansion was a need for new electrical generating capacity, both to meet new needs for industry, commerce, and a growing middle class of consumers and to fill a persistent gap between supply and demand. There was and still are chronic shortages of electricity in rural regions of China and one-third of the country lacks comprehensive grid coverage. In order to meet the need for new energy, the SPCC, in Beijing, supported an aggressive program of new power plant construction, with a goal of installing an additional 16 GW of new electrical generating capacity annually over the period from 1995 to 2000 [4]. This rate of expansion has at present been curtailed (1999) but new electrical generating capacity additions can be inevitably expected in the future.

Most of the near term planned electricity generating capacity expansion for China is expected to be met using coal-fired steam turbines in the 300 MW to 600 MW range, greatly increasing the reliance on coal for electricity production in the near future. Coal is gaining as the primary commercial energy source in China, rising from 74 percent in 1980 to 78 percent in 1995, compared to 24 percent worldwide in 1996 according to the International Energy Agency. Thus, China is uniquely dependent on a single energy source and is second only to the United States in coal consumption. Electrical generation is mainly from coal (about 75 percent), but consumes only 29 percent of coal burned in China today. By the year 2010, the World Bank projects that 40 percent of the country's coal production will be used to generate electricity. Coal production in China today is about 1.2 billion tons per year [3]. Together China and U.S. consumed more than half of the coal used worldwide for electricity production during 1996, according to the International Energy Agency [http://www.iea.org/stats].

Reliance on coal comes at a high price. Together coal and oil represented 93 percent of commercial energy use in China in 1991, producing more than 600 million tons of CO_2 emissions, or about 10 percent of the world's total. Coal burning produced 85 percent of China's total CO_2 emissions and 87 percent of total NO_X emissions in 1991. The primary cause of urban air pollution in China is coal combustion for space heating. Pollution concerns are not limited to mainland China. For example, the Ministry of International Trade and Industry in Japan announced in 1994 that it will support several reconstruction projects in the city of Shenyang in Liaoning Province in China, to help reduce acid rain in Japan.

Air pollution problems in China, which are some of the worst in the world, are further aggravated by rural households burning coal for heat and cooking, along with inefficient combustion of 173 million tons of fuel wood and 298 million tons of dry crop straws and stalks. Urban air pollution from vehicles, in the form of hydrocarbons, carbon monoxide, and nitrous oxides, is also increasing with vehicle registrations expanding 12-14 percent each year since the late 1970's [3].

Coal is also an infrastructure burden. More than 50 percent of China's rail transportation is used to transport coal from the production centers in the north and west regions of the country to the densely populated areas in the east and south. Reliance on coal for electricity production has forced China's strategic planners to incorporate major infrastructure projects in their electric capacity expansion plans for new railroad and coastal port facilities, and the building of power plants at coal mine sites (mine-mouth plants) with power transmission over several major new east-west and north-south transmission line corridors [5].

China's petroleum industry is going through major changes and facing large increases in consumption, mostly in the transportation sector. Since 1993, consumption of oil has exceeded domestic production and China has been a net oil importer. The 1998 reorganization of the two state owned oil and gas corporations, strengthened control over the two vertically integrated regional entities [4].

There is also a need for rural electrification. In 1998, there were 60 million people living below the poverty level in China, with most having no access to electricity. To accelerate the process of alleviating this abject poverty and improve the quality of life for these people, one effective measure is to utilize the rich renewable energy resources. In many cases, wind and solar energy resources are abundant in rural regions of China with urgent energy needs and a lack of conventional electricity supply grid.

Not surprisingly, there is a significant and growing interest in China in developing renewable energy and energy efficiency technologies to help meet energy demands and mitigate environmental problems. China has an abundance of renewable energy in the form of biomass, hydro, solar, wind, geothermal, and ocean tidal resources. China is already one of the world's largest users of renewables, primarily in the form of biomass and hydroelectric power. The central government in Beijing through various commissions and ministries has active programs for developing renewable energy in all of the areas mentioned above.

3.0

Protocol Activities

3.1 Annex I – Developing Cooperation in Rural Energy Development

The DOE and MOA signed Annex I, Developing Cooperation in Rural Electrification on June 27, 1995, as the first area of active cooperation and project development under the Energy Efficiency and Renewable Energy Protocol. The objectives of Annex I are to promote sustainable development in rural areas of China by accelerating the deployment of renewable energy systems, to demonstrate the technical and economic feasibility of these technologies for rural inhabitants, and to the facilitate formation of links between the Chinese and U.S. renewable energy industries. The scope of the Annex allowed for, but is not limited to, work on:

- Biomass gasification/electric power generation at the village level,
- Medium and large-scale biogas plants,
- Solar photovoltaic and solar hot water heater technologies,
- Small wind turbines, and
- Small hydropower and micro hydropower systems.

To date, the major projects supported to date under Protocol Annex I include: (1) a solar home system project in Gansu Province; (2) provincial household surveys for market characterization and rural electrification options analyses in Inner Mongolia, Xinjiang, Qinghai, and Gansu; (3) a remote household wind/solar hybrid system project in Inner Mongolia; and (4) development of a national biomass resource data base for China with corollary assessments and analyses. Details of these project activities are given in the following sections.

3.1.1 Solar Photovoltaic and Wind Hybrid Rural Electrification Systems Technology Descriptions

Solar photovoltaic energy technology, called “photovoltaics” or “PV,” employs solid-state semiconductor devices with no moving parts, that convert sunlight into direct-current electricity. Wind energy technology uses turbines to convert the kinetic energy in the wind into alternating or direct-current electricity. These technologies can be used individually, or in hybrid combinations with diesel electric generators, or connected to the electricity grid.

Solar and wind resources are vast and widely available in most areas of China. Solar energy is the most widely available energy resource in the country, especially in the north and western regions and in coastal zones and on off-shore islands. If harnessed, solar resources could meet the entire Chinese electricity need. However, such large scale use is not economically practical today. Wind resources are also geographically diverse and abundant. This resource is discussed in more detail under Annex II, later in this report.

Projects under the Annex I Agreement have focused on deploying small solar and wind power systems for lighting, communications, micro-enterprise, refrigeration, and other similar low-power applications. As a result living standards and quality of life of rural populations have been substantially improved in the areas that previously had no access to electricity.

There is a large market for small-scale, off-grid wind and photovoltaic power generators in northern and western China, and for inhabited coastal islands. The World Bank estimated that in the five northern and western provinces and autonomous regions of Qinghai, Tibet, Inner Mongolia, Xinjiang, and Gansu alone, there is a minimum of 2.2 million unelectrified households that are located in regions of China where grid power does not exist [11]. For more than 300 inhabited islands and potentially several thousand uninhabited islands which could be populated along the coast of China, the development of grid power in the near term is also not feasible. Renewable energy is one way to meet some of this need.

3.1.2 Gansu Province Solar Home System Project

Initial U.S.-China cooperation for rural electrification activities in China focused on the development of solar home system applications for western China. Generally, solar home systems in China for individual households start at 5 watts and can be 150 watts or larger. A typical solar home system in northwestern China consists of a 20 watt crystalline silicon PV module (Figure 2), a charge controller, a 38-ampere hour sealed lead-acid battery, two 8-watt compact fluorescent lamps, and necessary wiring. The retail price range of such systems is 1,800 to 2,400 RMB ($219 to $290 US), but the higher price systems are much higher quality and reliability. Many herdsmen and farmers can afford to buy these systems that provide light for children to read and study at night. Communication, via television and radio, is a prized addition and in some cases, a refrigerator and washing machine are purchased by more wealthy families [8].

The Gansu project is being implemented by the Solar Electric Light Fund (SELF) in Washington, D.C. and the Gansu Solar Electric Light Fund (GSELF) in Lanzhou, Gansu, and builds upon work previously conducted by these organizations. The objective of the project is to provide electricity to more than 600 remote homes and schools during the course of the project and to help to build an infrastructure for sustainable technology deployment. Technical assistance for capacity building includes: support for the development of a distribution network for sales and service, a comprehensive training program, and experimental financing of systems through cash and credit sales. As of the fall of 1998, 320 systems had been installed in the joint U.S.-China project and another 275 systems had been installed by GSELF with the support of the Gansu Provincial government. In addition, ten 53-watt PV school systems using Solarex modules had been installed.

Figure 2. A typical solar home system in Gansu Province in western China

The lack of credit experience in rural China necessitates continued experimentation with installment credit terms to develop a functional credit system. The Gansu project is directed toward poor communities in rural Gansu, using limited subsidies that are being phased out during the course of the project. The province of Gansu has among the lowest annual income levels in all of China for remote farming communities. A revolving-fund account has been set up at the Lanzhou Branch of the China Construction Bank by SELF and GSELF to leverage the project by using customer receipts to purchase more systems.

The demonstration projects and infrastructure developed under this program are models for similar activities in other regions and government and private agencies throughout China. The State Council Office for Poverty Alleviation and Rural Development in Beijing is a key funding partner working closely with MOA. This Office has a primary responsibility for rural development projects in

China and spends more than $1 billion (U.S. dollars) per year on rural infrastructure projects. The Gansu project is providing a mechanism for introducing the support of renewable energy technologies into the strategic planning activities.

A barrier to the widespread deployment of PV in China has been the variable quality of modules and balance-of-system components. Quality control was introduced through component testing and system monitoring during the Gansu project. NREL provided three PV modules previously calibrated under standard test conditions, for use as secondary testing standards in quality control protocols. Also, an extensive training program was included in the Gansu project to train users and installers and teach marketing techniques to village technicians and rural energy officers. The seminars taught basic principles of solar electricity as well as PV design, installation, and maintenance. As a result of the Gansu project, MOA is establishing a regional testing and training center in Lanzhou. MOA has rural energy offices in 1,800 of the 2,300 counties in China that could be involved in future projects.

3.1.3 Inner Mongolia Household PV/Wind Hybrid Systems Pilot Project

The Inner Mongolia Autonomous Region's (IMAR) government has been aggressive in developing renewable energy resources for both grid-connected and off-grid applications. Over the past 10 years, more than 120,000 households have been electrified with small wind generators in the range of 100 to 300 watts. In addition, more than 7,000 small PV systems (total of 120 kW) have been installed in remote households. However, there are still more than 300,000 remote households, 1,100 villages, and 198 town-ships that are unelectrified in remote rural regions of IMAR. By the year 2000, the New Energy Office of IMAR plans to install 25,000 remote household systems using wind, PV, and wind/PV hybrid systems and in the longer term a total of 80,000 systems throughout IMAR. The use of subsidies for rural systems is being phased out and commercialization based on market forces is being encouraged. The rural population of Inner Mongolia, consisting of herdsmen and farmers, has among the highest annual income levels of the rural populations in China.

Annex I cooperation is assisting the New Energy Office of the Science and Technology Commission in Hohhot in the development and deployment of PV/wind hybrid household systems in Inner Mongolia. Other partners include the Inner Mongolia Polytechnic Institute, the University of Inner Mongolia, the Chinese Academy of Sciences in Beijing, the Shangdu Machinery Company in Inner Mongolia, and the JiKe Company in Beijing.

Renewable Energy Options Analysis – In the first phase of the cooperation in IMAR, the University of Delaware, NREL, and the Inner Mongolia team completed a levelized cost analysis of rural electrifica-tion options for several counties. The analysis compared renewable energy options with conventional gasoline engine driven generator sets based on local renewable resources and costs [10]. Beginning in 1995, NREL, the Center for Energy and Environmental Policy at the University of Delaware, and the Chinese Academy of Sciences in Beijing initiated a case study analysis of rural electrification options in IMAR. The project was conducted in cooperation with the Planning Commission and the New Energy Office of IMAR, which are the two key agencies responsible for renewable energy planning. Other participating organizations included the University of Inner Mongolia, the Inner Mongolia Polytechnic University, and several local companies.

The case study project involved levelized cost analyses of existing systems in four counties in the central and northern regions of IMAR, including Si Zi Wang, Su Ni Te You, A Ba Ga, and Dong Wu Zhu Mu Qin counties. Solar and wind resource data were collected from the four counties and performance/load data were collected from 10 PV systems, 22 wind systems, and 6 PV and wind hybrid systems, which were in the 22 to 600 watt range. Two sizes of gasoline engine driven generator sets, common for household and ranch use, in the 450 to 500 watt range were evaluated for comparison.

The results of this first phase of the case study, the levelized cost-of-energy analyses, are shown in Table 1. For the types of systems currently being deployed for stand alone electrical generation in rural areas of IMAR, wind generators are the least-cost option for household electricity in the four counties. Small wind generators in the 100-, 200-, and 300-watt size range are manufactured locally in IMAR for the household market. The levelized cost of energy for small PV/wind hybrid and PV systems is higher than the cost of electricity generated by wind systems, but all of these renewable systems options result in a significantly lower cost of electricity compared to gasoline engine generator sets [7 and 9].

Study results show that designing optimized wind/PV/battery-storage hybrid rural household systems depend primarily on the local wind/solar resource mix and on the annual electric power demand for a given household-load. Normally, hybrid systems are more reliable and economical than wind or PV systems alone. The use of small wind/PV hybrid systems for remote-household electricity is attractive because of the complementary seasonal solar and wind resources.

The New Energy Office of IMAR and the Inner Mongolia Planning Commission are developing plans for expanding the use of wind/PV hybrid systems by remote herdsmen's families for household electrification. NREL and the Center for Energy and Environmental Policy at the University of Delaware are providing technical assistance to these agencies in optimizing the design of such systems. Based on annual income levels, two types of systems are receiving attention. Hybrid systems in the 400 to 500 watt range are being developed to serve household loads that include lighting, a color television set and radio, a small washing machine, and a small freezer, requiring approximately 1.6 kWh per day of energy. Smaller systems in the 150 to 200 watt range are being developed for intermediate-income-level households that provide approximately 0.6-0.7 kWh per day for household loads that do not include a freezer or washing machine. A pilot

Table 1. Levelized Cost of Energy Values for Rural Electrification Options in Inner Mongolia

System	Output range (kWh/yr)	Levelized cost based on Mfr. quoted battery lifetime ($/kWh)	Levelized cost based on battery lifetime from field analysis ($/kWh)
Wind only	200-640	0.24-0.37	0.50-0.63
PV only	120-240	0.67-0.73	0.77-0.83
Small hybrids	400-750	0.31-0.46	0.57-0.72
Large hybrids	560-870	0.32-0.46	0.43-0.57
Gen-sets (not serving continuous duty cycle applications)	660-730*	0.76-0.80*	0.76-0.80*
Gen-sets (serving continuous duty cycle applications)	480-560	1.09-1.19	1.16-1.27

*Source: University of Delaware. [10] *These estimates are based on systems configured without storage.*

project based on remote-household hybrid systems is discussed below. The results of this pilot project will be fed into the planning process for the larger 25,000 and 80,000 remote-household projects by the IMAR government. A system monitoring component of the project will place data acquisition systems in several households to collect system performance data and solar and wind resource data.

Figure 3. 500-watt PV/wind hybrid household system in Inner Mongolia. *Courtesy of Wang Sicheng, JiKe Company.*

Pilot Projects for Home Based Solar/Wind Systems– Current cooperation with Inner Mongolia is focused on completing the installation of 240 PV/wind home based systems during 1999. The typical demonstration system consists of: (1) a 100-watt wind turbine combined with 50-70 watts of PV or (2) a 300-watt wind turbine combined with 150-200 watts of PV, with battery storage. These systems are capable of delivering 0.6 kWh/day and 1.6 kWh/day, respectively, with high reliability. The systems provide energy for lighting, color television, consumer electronics, and some discretionary load. Systems of 450-500 watts (Figure 3) can also maintain a refrigeration load. Food storage by freezing is a major driving force for larger system development, even in colder climates. Summer is very hot in Inner Mongolia which borders on the southern edge of the Gobi desert.

An attractive option for household systems resulting from the analysis and prior research in Inner Mongolia is, PV/wind hybrid systems with battery storage. These systems are more reliable than PV or wind systems alone because of the seasonal wind and solar resources, with wind relatively more available in winter months and solar relatively more available in summer months. Analyses show that wind, PV, and PV/wind hybrid systems are lower-cost options for rural energy systems than fossil-fueled generators [7 and 9].

3.1.4 Expansion of the Solar Home System Project

Building on the successful projects in Gansu and Inner Mongolia, with technical and planning assistance from DOE and NREL, the MOA initiated a new 10,000 solar home system project in 1998. This will be conducted in six northwestern provinces and autonomous regions: Xinjiang, Qinghai, Gansu, Inner Mongolia, Ningxia, and Shaanxi. After the government restructuring in 1998, the implementation of this project has been transferred to local government authority. An additional impact of restructuring, was the transfer of the authority for managing Annex I activities in the MOA from the Chinese Department of Environmental Protection and Energy to the Department of Science and Education.

In parallel with the 10,000 solar home system project, a market characterization survey is being conducted in Qinghai and Xinjiang Provinces. Five counties were selected in each province for collecting data. All ten counties are also members of the National One Hundred Counties Integrated Rural Energy Development Program. The survey is designed to collect a statistical sampling of rural household data in each province to characterize households in terms of socioeconomic parameters, including family size, income levels, potential electricity needs aimed at assessing willingness to pay for household systems. Technical data is also being collected on performance of operating rural electrification systems; electricity production; fuel consumption; wind; and solar, wind, and other meteorological data, to conduct rural electrification options analyses. Through the survey, the market potential for PV/wind home system applications in the targeted provinces will be better understood and the social and economic factors affecting the sustainable deployment of renewable energy technology will be evaluated. Finally, the priorities for PV/wind home systems development in northwestern China will be determined.

The Department of Science and Education in the MOA is responsible for the day-to-day work of the project. MOA established a steering team and an expert team for the project. The Department of Science and Education heads the steering team. Team members include personnel from the State Council Office of Poverty Alleviation and Development, the Center for Energy and Environment Protection under the MOA, and the heads of the rural energy offices in the six northwestern provinces. In the U.S., the University of Delaware, will be responsible for data analyses and assessments, in collaboration with the expert team in China.

The functions of the project steering team in China are to formulate measurements for completion of the project objectives; to provide guidance for the project; to coordinate the central and local government and institutional project participants; to ensure the successful implementation of the project; and to organize the necessary working meetings, training activities, and workshops. The Institute of Energy and Environment Protection under Chinese Academy of Agricultural Engineering chairs the expert team. The working team for the project includes national experts on PV and renewable energy technologies, economics, and local administration officials.

The survey and analyses will be completed by the end of 1999. The surveys also complement an expansion of the survey work done in Inner Mongolia and will be supplemented by a survey of the solar home systems and households installed in the joint project in Gansu.

3.1.5 Information Exchange Workshop

A workshop focusing on the use of small wind and solar-photovoltaic technologies for rural electrification in China was held on September 16-18, 1998, in Beijing. The workshop was jointly funded by the DOE, the Asia Pacific Economic Cooperation Program, and the Chinese MOA, with the assistance of the Center for Renewable Energy Development (CRED) in Beijing. The objectives of this workshop were to: (1) provide information to U.S. and Chinese businesses on rural electrification opportunities and plans for China, (2) provide a forum to facilitate networking of U.S. and Chinese company representatives, and (3) develop a strategy for fostering U.S.-Chinese joint venture and other business activity in rural and remote renewable energy electrification in China. The workshop was attended by over 70 Chinese and U.S. business, government, and NGO representatives. U.S. participants included: Solarex, Siemens, ASE America, EPV, USSC/ECD, Ascension Technology, SELCO, WINROCK, Bergey Wind Company, Atlantic Orient Corporation, and several rural electrification experts. There were more than 15 Chinese companies in attendance.

3.1.6 Biomass Systems – Technology Description

The use of biomass energy conversion technology can be categorized as direct burning, physical conversion, bioconversion, liquefaction, and solid waste processing technologies. Each of these classifications can be further divided into particular processes shown in Figure 4. Research being done under Annex I of the Protocol is concentrated in three areas: technology for large and medium-scale biogas projects on animal farms, technology for thermolysis gasification of biomaterial such as agricultural residues, and on technology for the treatment of urban solid waste (garbage) [12].

Biomass resources are most extensively available and in use in the heavily populated regions in eastern and southern China. In 1996, about 220 Mtce, or 14% of China's total energy consumption came from biomass sources including wood, crop residue, animal waste, and other forms [12, Chapter 1]. Bioenergy use declined slightly from earlier estimates, as coal and electricity use increased. However, in rural areas biomass supplied 38% of overall energy consumption and 77% of fuel used on farms [14, Chapter 5]. In many parts of China, the biomass resource is sufficient to supply village-scale energy systems for both thermal and electrical energy.

There has been substantial growth in the agricultural sector in China. As the population grows there is need for more efficient and productive farming processes (if China is to remain a net exporter of food products). To date grain production has kept up with population growth [6]. Farm animal production has also grown dramatically. Examples of annual average increases are shown in Table 2. Agricultural growth is producing increased biomass wastes and resulting in an increasing demand for energy in the farming business sector. Improving standards of living are causing increased demand for many products. People in the cities are favoring lean pork and fresh eggs. Milk is no longer regarded as a luxury food. These trends are expected to continue, and resulting energy demand expansion and pollution will become more serious issues. [17]

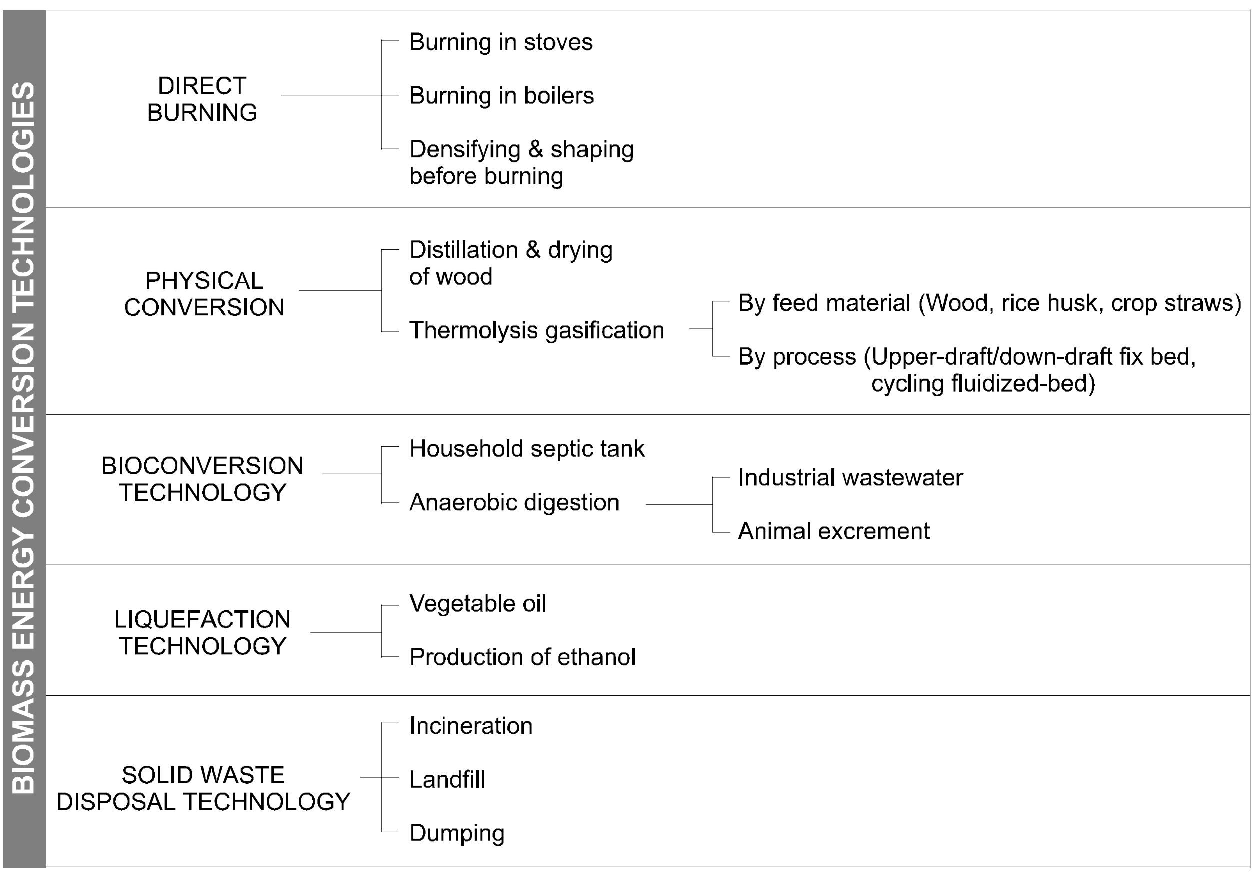

Figure 4. Categories of Biomass Energy Conversion Technologies

Table 2. Growth Rate in Farm Animal Production

	Annual Average Growth Rate (%)		
	1980-1984	1985-1989	1990-94
Cattle	4.7	3.8	6.5
Pigs	6.5	5.0	8.0
Chickens	20.5	19.8	22.9

Source: Chapter 2 in Ministry of Agriculture Report, Assessment of Biomass Resource Availability in China, 1998 [14].

The DOE, NREL, and the MOA are working together to evaluate the commercialization of biomass energy conversion technologies in the framework of a market-oriented development strategy. The initial phase of the cooperation involves assessing the market size, technology status, and the potential for biomass power projects in China. Information from phase one will then be used to formulate policies and design investment strategies, accelerating the pace of market-oriented development and implementation of biomass energy technologies. Resource availability is being characterized by developing a database of the mainstream resources. These resources include agricultural crop residues, animal waste, sugarcane residues, fuel wood, and urban wastes. A geographic overlay at the provincial level, and at the county level in high potential areas, is applied to the resource data to create an initial GIS (geographical information system) database.

3.1.7 Biomass Resource Assessment

China has abundant biomass resources, fourth largest after coal, oil, and natural gas. The energy resource in rural agricultural discards (e.g. straw and stalks) is estimated to be 308 Mtce every year. Firewood resource is 130 Mtce. Together with animal excrement and city waste, the total biomass resource available annually is likely to be more than 650 Mtce, which is nearly half of the total energy consumption in China in 1995. [14, Chapter 1]

As much as 38% of the energy used in China's rural areas comes from biomass in the form of fuel wood, straws and stalks, and animal residues [12]. Most of this bioenergy is produced and consumed for the daily living needs of about 700 million rural inhabitants. However, as people's incomes rise, so does demand for "modern" fuels that are cleaner and more efficient for cooking and heating. It appears that current forms of biomass and bioenergy use will decline and the use of LPG and kerosene will increase. Modernization of biofuels would offset increasing rural area fossil fuel use, improve the environmental performance of biofuels, and retain incomes and jobs in rural areas [13 and 14].

Data from research and analysis of existing Chinese demonstration projects contains a wealth of information on bioenergy technologies. Technologies of special interest that are being studied under the Protocol agreement include: (1) biogasification technologies on a medium and large scale for combined heat and power, utilizing manures, (2) biogas technologies for treatment of urban solid wastes including landfill power generation, and (3) thermal gasification technologies for the integrated production of gas for cooking, industrial/community uses, along with combined heat and power the utilizing agricultural wastes. Case studies for major technologies at selected sites have been prepared that account for: (1) social, energy, environmental, and developmental strategies of selected project locations, (2) attitude and capacity of local government and inhabitants to support projects, (3) project financial and economic analysis, and (4) comparative analysis of grid-connected and stand-alone options for projects.

3.1.8 Biogas from Animal Waste Project

Excrement from animals can be processed in large anaerobic digester tanks to produce combustible biogas, fertilizer, and water emission. This process is shown in Figure 5. In China, during the 1970s and early 1980s, biogas plants were built on animal farms primarily to alleviate energy shortage in rural areas. Now, however, both the United States and China have significant environmental challenges as a result of intensive livestock production and industrial processes (e.g. distillery) that create high COD and BOD (Chemical and Biological Oxygen Demand) waste streams that often end up in rivers, lakes, and estuaries. This situation can deplete natural dissolved oxygen, resulting in algae blooms and negatively affect fishing and drinking water. The anaerobic digestion process can reduce the organic matter in the waste streams by up to 90%.

China has developed over 460 large scale anaerobic digestion units that produce 20 million cubic meters (m^3) of biogas annually, supplying 56,000 homes and 866 kW of electric power generation. Waste processing developments and the operating experience base are of potential interest in the United States. Consequently, an area of joint research is to determine the commercial viability of biogas production facilities. The modern production process is described in Figure 5. Animal fecal material is the primary input, with biogas, vegetable fertilizer, fish feedstock, grass fertilizer, and potable water as outputs.

One of the Biogas pilot projects is located at the Xinghuo breeding farm near Shanghai. This farm covers 22 km^2 and employs 6,600 people. The cow manure output is used to produce about 0.75 million m^3 of biogas annually, enough to meet the cooking and hot water needs of 3,200 households and 14 restaurants. This type of project may have numerous applications in the United States and around the world.

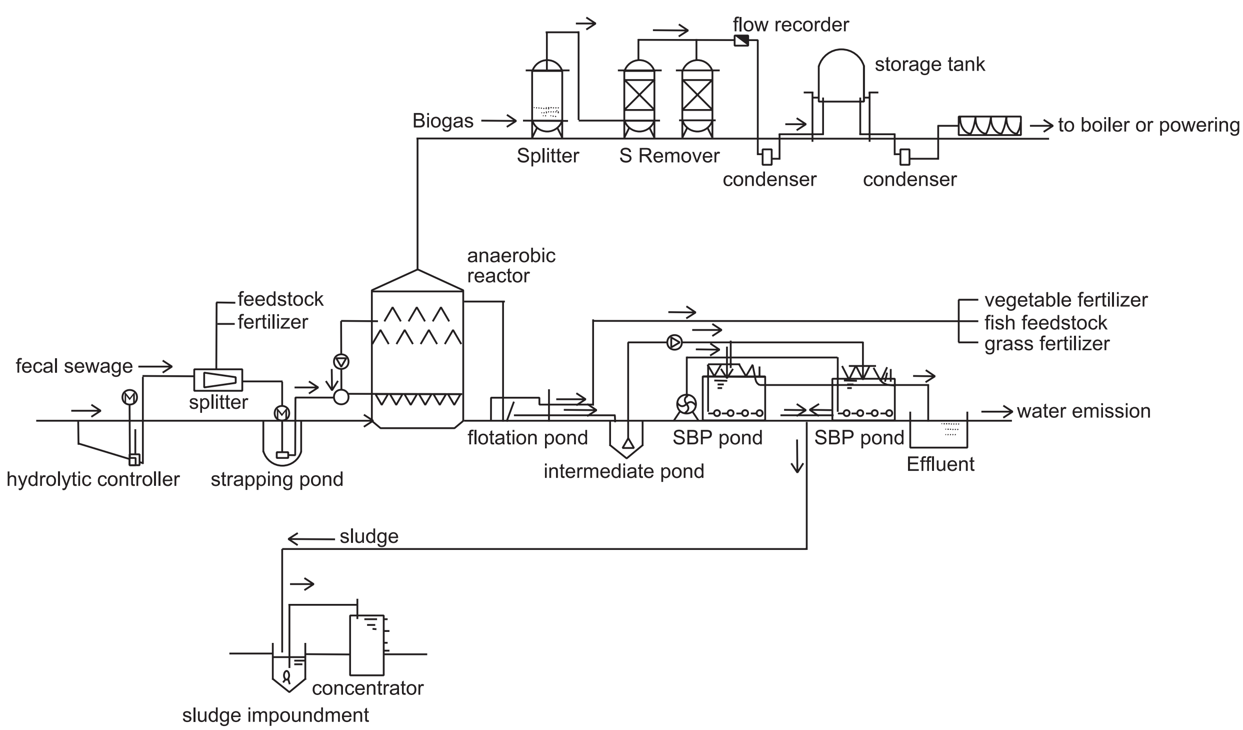

Figure 5. Flow Chart of Typical Animal Waste Biogas Demonstration Project

3.1.9 Biomass Gasification from Crop Straw Project

Co-firing of straws and stalks (Figure 6) with coal is an important area of cooperative research under this Annex. The increasing surplus of agricultural residues and their poor disposal by field burning is causing environmental problems. In provinces that have extensive coal fired electricity generation and also have large industrialized grain production such as Heilongjiang, Jilin, and Liaoning, the MOA has proposed that co-firing be investigated. Joint studies between MOA and NREL are expected to lead to pilot projects involving the power bureaus. Technical exchanges from similar projects in the U.S. are being conducted with China to evaluate project economics and technical issues.

Figure 6. Straw and Stalks Agricultural Residue.

Another approach is to convert biomass into gaseous fuel through a thermochemical gasification process. The basic principle is to heat biomass materials sufficiently to break the chains between organic carbon-hydrogen compounds with high molecular weight and decompose them to gaseous hydrocarbons with light molecular weight, such as carbon monoxide or hydrogen. This kind of conversion will change the biomass material into a form that can be used more conveniently. The product also has a much greater energy conversion efficiency than direct combustion of solid biomass. From Table 3, we can see the gasification features of various biomass fuels and coal. Also, it is clear that coal is an attractive fuel with a much higher energy content in both solid fuel and gaseous forms.

There are three typical gasification techniques: distillation, rapid pyrolysis, and gasification. The first two are suitable for pyrolysis of wood or wood chips; the last is for gasification of stalks of crops such as corn and cotton. Because of the wide distribution of crop stalk resources, and the rapid increase in demand for clean, convenient rural energy, research is focused on gasification technologies [18].

Shandong Academy of Sciences developed crop stalks-based biomass gasification and centralized gas-supply system technology. In this process crop stalks are converted into combustible gas with low caloric value in a down-draft, fixed-bed gasifier, then the particulates and tar are removed from the gas, and finally the gas is delivered to households as living fuel for cooking through centralized gas-supply system in a range of village units. See Figure 7. After more than 10 years of research, currently there are four demonstration systems operating successfully in Dongpan, Zhangsan, Tengzhai, and Xunjia villages. Each village system includes a crop stalk-based gasifier set, key equipment for a centralized gas-supply system, gas pipeline facilities and their customers, household gas stoves, etc. After the first demonstration sites were made operational in pilot villages, a total of 14 sets of gasification equipment have been disseminated for use and are currently running in Shandong Province. This kind of gasification system with a scale of 100-200 households is also being demonstrated in other areas, including Beijing.

Table 3. Gasification Features of Various Fuels.

Fuel type [1]	Fuel features				Gasification intensity	Gas production	Heat value of gas
	Humidity (%)	Ash content (%)	Size (millimeter)	Heat value (MJ/m^3)	(kg/m^2-h)	(m^3/kg)	(kJ/m^3)
air-dried wood	25	1.0	80-100	13,600	200-250	2.2	4,273
wood wastes	23	1.0	sawdust	13,600	260	2.3	4,360
wheat stalk and rice straw	10	3.5	cracked	14,700	180-220	2.3	4,690
cowpat	16	6.0	50*50	11,700	200-230	2.2	3,908
leaves	10	5.0	natural size	13,800	200-230	2.0	3,694
coal (washed Pennsylvania Bituminous)[2]	6.5	6.5		24,300		2.0 [3]	12,300 [3]

Source: [1] Biomass energy conversion technology, Northwest University Press (Xian: China), 1993.
[2] Mechanical Engineers Handbook, Editor M. Kutz, Wiley Interscience, 1986.
[3] Perry's Chemical Engineering Handbook, McGraw Hill, 1984.

3.1.10 Biogas from Municipal Refuse Landfills Project

Landfills are different from natural dumps. The natural dump is used to dispose of refuse in wastelands or ditches without any cover or scientific disposal. Natural dumping was used in many cities in China prior to the 1980s. The disadvantage of this technology is obvious. Due to exposure of the refuse to air; bad odors, flies, mosquitoes, and mice proliferate ruining the ecological system near the dump site and endanger public health. Meanwhile, percolating water, heavy metals, and other harmful pollutants decomposed by microorganisms from refuse seep underground and pollute water resources.

Landfill disposal is a mature technology, developed to reduce environmental problems by preventing secondary pollution while producing combustible gas. Biogas from landfills can be collected by pipeline and used for power generation or chemical production. At present, 4,817 landfill plants have been built world wide and are producing more than 5.1 billion m^3 of biogas annually, equal to 2.4 million tons of crude oil.

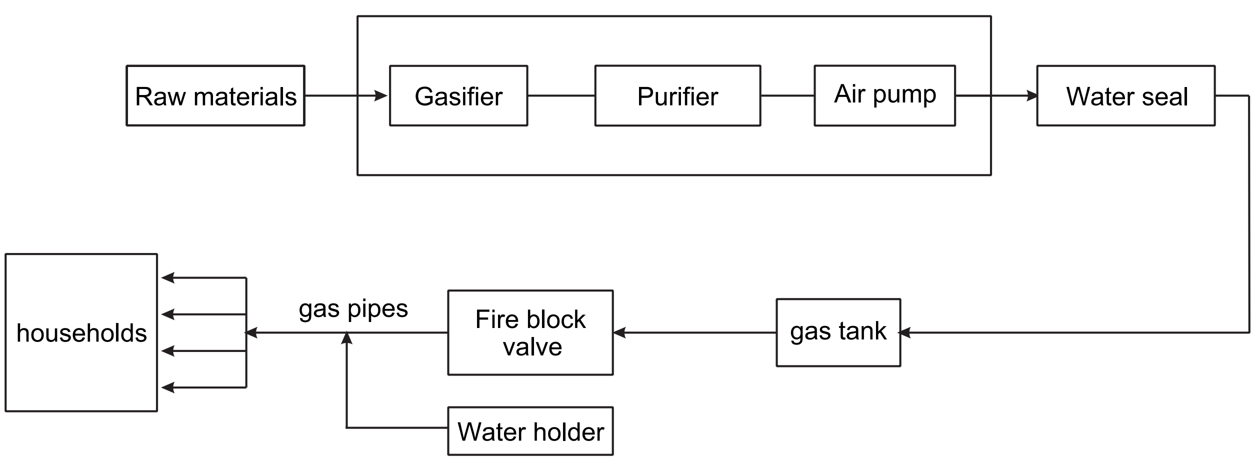

Figure 7. Configuration of Biogasification and Distribution System Demonstration Project

Landfill is just one of the municipal refuse disposal technologies. Incineration is another process. Each method has its own advantages and can be applied in different situations. Landfills are popular in many countries because they are simple to operate, low cost, and suitable for various kinds of refuse and energy recovery.

One of the goals of the research under Annex I is to help China introduce landfill technologies and to solve technical and secondary pollution problems. Specific research efforts are aimed at reducing land area requirements, improving efficiency and reducing leaching as follows:

- Raising the height of landfill plants to save land and decompose refuse faster, producing biogas;
- Adopt new materials and technologies to strengthen the under-pile impervious barrier and by installing a sewage disposal system to prevent pollution to water resource;
- Pipeline shaft drilling, pipeline construction, and condensed water removal;
- H_2S control;
- Refuse leaching solution and biogas collecting pipelines are built to increase the biogas collecting efficiency; and
- Compacting the refuse to prevent air from entering the refuse and avoid aerobic reaction.

In general, along with the improvement of landfill technology and more operating experience, landfill technology is maturing and information is being disseminated through the Annex activities on the following technical topics:

- Collaborative research, technical assistance, and scientist exchanges and
- Technical publications and conferences.

The Chengdu Institute of Chinese Academy of Science is the leading organization developing landfill technology in China. Their accomplishments include: completing the research of biogas production from refuse anaerobic osmosis for 1985-1986, research of municipal organic refuse systematic disposal during 1987-1990, and a 160 m^3 pilot-scale test. More recently, “harmless landfill” projects are being constructed. Eight have been completed are in operation.

The use of landfill biogas is playing an increasingly important role in power generation. Combustion equipment consists of internal combustion engines or turbines. Otto cycle internal combustion engines and diesel engines are most commonly used. Gasifiers can be added to provide properly mixed gas to the combustion engine for use in the landfill plant.. Gas turbines and steam turbines are also being applied in some plants. The advantage of a gas turbine is its large output per unit weight, about 70-140 kW/ton, much higher than 27 kW/ton for internal combustion engine and 10 kW/ton for steam turbines. Internal combustion engines are lower cost however, and are used more in China while turbines are used more in landfill plants in the U.S. In China, some small internal combustion engine generators are portable and are moved from one landfill plant to another.

Landfill research and development taking place in China is focused mainly on internal combustion engine applications. Efforts are aimed at developing simple modifications for gasoline and diesel engines that can potentially be manufactured in China as biogas engines. Although some landfill plants are successfully operational in China, the landfill technology is generally very small scale. Research to date concludes that the engine type used in landfill power projects will depend on the biogas production. Internal combustion engines are suitable for capacities from 1,000 to 3,000 kW; if the needed capacity exceeds 3,000 kW, gas turbines, with higher efficiency, are a better choice although they are more costly.

3.1.11 Village Scale Biogasification Power Projects

A major focus of the ongoing bilateral cooperation, is the use of biomass at the village level for electricity production. One system that is being evaluated in detail consists of a thermal gasification unit that delivers low calorific value cooking gas directly to households. This biogas, which is cleaned and cooled for distribution, could also be used in efficient engines to generate electricity. One concept being evaluated is the use of a Sterling motor at around the 25 kW output level. With technical assistance from NREL, three case studies are being performed in three provinces in detail, including Zhejiang, Shandong, and Sichuan. A techno-economic analysis of a gasification project using crop straw to produce cooking fuel at the village level has been completed for Shandong, resulting in demonstration projects funded entirely by the Chinese in 10 villages with an additional 24 being planned.

3.1.12 Reports

Three major bilingual reports have been published as a result of the bilateral cooperation for resource assessment in China, including:

- "Assessment of Biomass Resource Availability in China," [14]
- "Biomass Energy Conversion Technologies in China: Development and assessment," [12] and
- "Design for Market-oriented Development Strategy of Bioenergy Technologies in China," [15]

A CD-ROM has also been produced containing a complete national biomass database developed during the cooperative effort, entitled: "Evaluation of Commercialization of Biomass Energy Conversion Technologies and their Market Oriented Development Strategy." These information products are available from the NREL and MOA.

3.2 Annex II – Wind Energy Development

The DOE and the Ministry of Electric Power (now called the State Power Corporation of China – SPCC), signed Annex II in October 1996. The objective of Annex II is to promote the sustainable, large-scale deployment of wind energy systems for both grid-connected and off-grid village power applications in China. This is to be done by information exchange, training and demonstrating the technical and economic feasibility of wind energy technology to enhance its commercialization in China for the benefit of both countries.

These objectives are being met through a variety of cooperative activities. The Annex II activities are in three categories: (1) analysis and pilot project demonstration of various wind power applications, (2) information exchanges, and (3) collaborative research and exchange visits. Activities are designed to support China's goals to install 1,000 MW of wind systems by the end of year 2000 and 3,000 MW by 2010 [20]. The DOE supports China's goals and is hoping to create new business opportunities for the wind industry in both countries.

Through NREL, the DOE has provided training and the exchange of technical information between U.S. counterparts and Chinese Institutes entering the renewable energy field. Through this program, researchers and companies in the U.S., have learned about the electric power system in China. Chinese visitors have gained first hand experience using American built wind turbines, laboratory equipment, and commercially available software.

To date, four personnel exchanges have been completed on wind energy topics. Visiting scientists and engineers were give specific research topics and sent to work at the National Wind Technology Center for two to three month assignments. Specific training assignments were: (1) wind resource assessment and data collection methods, and wind project planning techniques for two engineers from the SPCC's Hydropower Planning General Institute, (2) economic analysis of large scale wind power plants connected to the Northeast China grid done by an engineer from the Electric Power Research Institute for the SPCC, and (3) a study of hybrid power systems using wind turbines for remote village power applications in Tibet by an engineer from the Research Institute for Electrical Engineering of the Chinese Academy of Science. To increase the involvement with U.S. industry, the Chinese visitors participated in the American Wind Energy Association annual conference and attended the intensive one week Wind Energy Applications and Training Symposium (WEATS) sponsored jointly by the wind industry, the DOE, and the U.S. Agency for International Development. Additional personnel exchanges are planned for 1999 and 2000.

3.2.1 Technology and Application Descriptions

Wind energy systems are one of the most promising new renewable energy technologies for China to providing significant amounts of electric power to the national grid and to provide electricity for many people in rural areas beyond the reach of the grid. Wind energy resource potential in China is estimated to be between 160 and 253 GW [1 and 21]. In contrast, the total installed generating capacity (including thermal, nuclear, and hydropower plants) in all of China in 1995 was 217 GW. The wind data was compiled by the Chinese Academy of Meteorological Science and included the total amount wind energy technically available to be utilized, without considering economic and social constraints. Of course practical constraints would preclude meeting the entire national electricity demand from wind turbines alone. The intermittent nature of the wind and constraints on power transmission would make such large scale use impractical, but the potential for using grid-connected wind power is huge in many diverse regions in China. The best wind sites were found along the southeast coast and in northern areas inland in the

Provinces and Autonomous regions of Inner Mongolia, Xinjiang, Heilongjiang, Gansu, Jilin, Hebei, Liaoning, Shandong, Jiangxi, Jiangsu, Guangdong, Zhejiang, Fujian, and Hainan. There are also isolate sites with good wind energy potential in most other Provinces.

Wind Energy Applications Analysis and Development – The SPCC and World Bank recognize that there is tremendous potential in wind power in China. There are three primary categories of applications for wind energy systems. (See Figure 8) First, wind turbines are being installed in large scale wind power plants, typically 20 to 100 MW in total capacity, that can produce electricity that is distributed through the national grid. This is the largest potential application for wind power, with at least one 100-MW plant expected to be on-line by the end of year 2000 in Inner Mongolia.

The second type of application is to install wind turbines in townships and villages for rural electrification and to reduce the use of expensive and heavily polluting, diesel engine driven generators in areas that are beyond the reach of the national electricity grid system. These off-grid applications may include installing clusters of smaller wind turbines in the size range for 10 to 100 kW each, on off-shore islands, in isolated communities, and for enterprises that generate their own power.

The third application of wind power is in individual homes to provide electricity for light, communications (television and radio), health, and comfort (refrigeration, washing machines and heat). These applications can be used with solar/photovoltaic and small gasoline engine power generators and are discussed in detail in Section 3.1 above.

China's Progress in Wind Power Plant Deployment – The total capacity of wind turbines in China was 223 MW by the end of 1998. The progress in wind power development in China has been the fastest in the renewable energy field. Since the first International Conference on Wind Energy was held in Beijing in 1995, wind power plant installations have increased ten fold. Currently 12 provincial and autono-

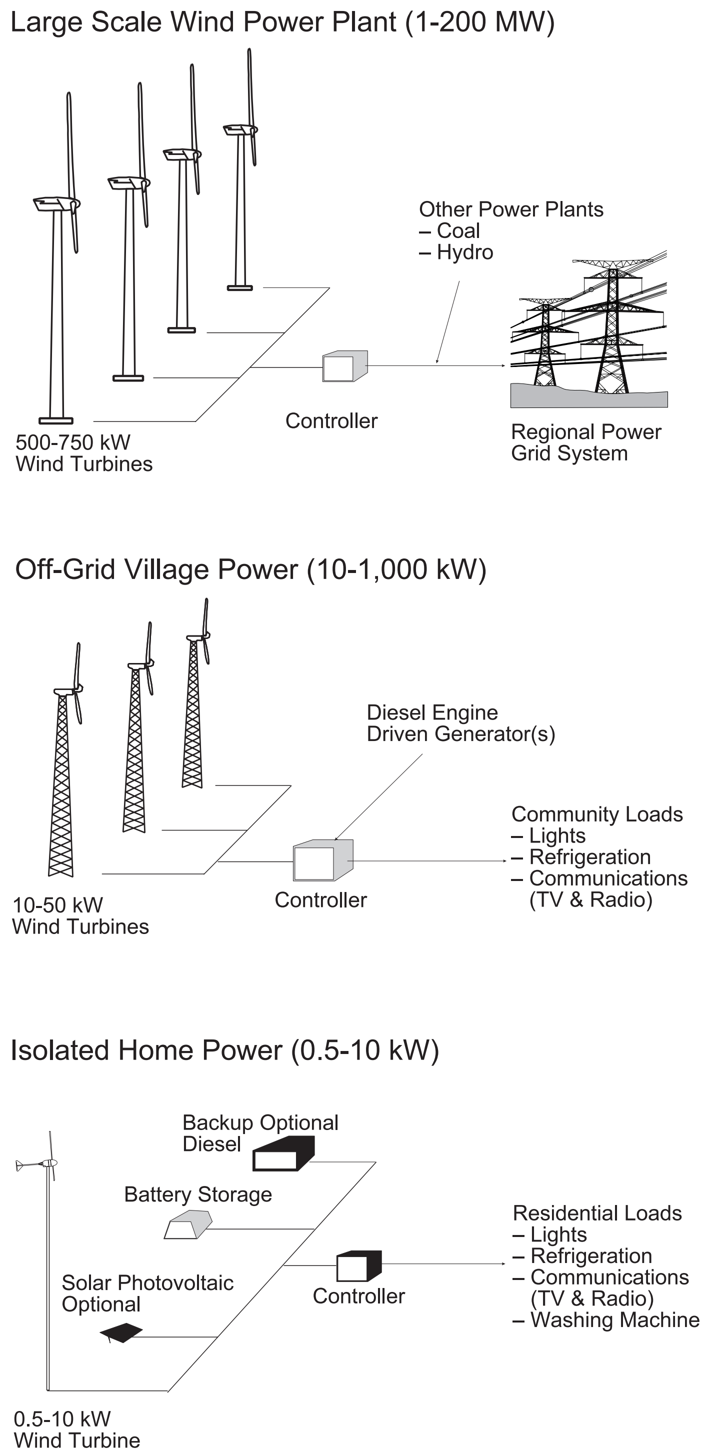

Figure 8. Typical-Wind Energy Applications in China

mous power corporations are engaged in developing wind power and 19 wind farms have been established in two high wind zones in China. Up to now, Xinjiang Dabancheng Wind Farm, with a capacity of 64 MW, is the largest wind plant in China. Guangdong Nanao Wind Farm, with a capacity of 42 MW, is the biggest island-based installation in Asia.

Many Channels to Construct Wind Plants and Attract Capital – China's wind power industry was financed initially using construction capital from Denmark, the United States, Germany and The Netherlands. From 1994 through 1997, there was more than $57 million USD in foreign investments in wind plants in China, most in the form of tied-aid grants and loans. More recently, construction of wind plants has been included in the central government plans and projects are being planned using commercial financing from the World Bank, the Global Environmental Facility, and the Asian Development Bank.

Technical and Economic Progress in the Industrialization of Wind Power – China has adopted rules and regulations to encourage wind power deployment. Many home owners, farmers and herdsmen in rural areas can now independently buy, install and operate small turbines. Wind farm owners can now independently construct, install, and operate wind turbines following the technical documents provided by the turbine manufacturer. Several factories on China now have experience manufacturing wind turbines in sizes from 0.1 kW to 300 kW. Larger turbines, up to 600 kW, can also be assembled in domestic factories. Many joint ventures for manufacturing wind turbines will be established in the future. Experts in a wind energy magazine said, "It was the China Wind Power Year in 1997."

3.2.2 Wind Energy Resource Assessment in Southeast China

Wind energy resource estimation and mapping are one of the first steps in planning wind energy projects and this was one of the initial areas of cooperation under the Wind Energy Annex to the Protocol. This task was supported by U.S. DOE, Environmental Protection Agency, and the American Wind Energy Association through a program called the Energy Technology Initiative. On the Chinese side, participation involved the State Power Corporation of China through the Hydropower Institute and the Chinese Meteorological Service.

Wind Measurement Program – The first part of the wind energy assessment task was to initiate a wind measurement program to collect detailed meteorological data needed to evaluate the energy production potential at sites under consideration for future large scale wind power plant projects. SPCC installed wind measurement stations at 12 locations; one near Shanghai, two in the Poyang Lake region near Lu Shan in Jiangxi, and at sites along the coast in Fujian and Guangdong. U.S. built anemometers for measuring wind at two heights were installed along with digital data collection systems. Chinese technicians and engineers were trained on installation, operation, and maintenance of the equipment as well as methods for analyzing and interpreting the results. To date, several thousands of hours of wind records have been compiled by the 12 systems and the results are providing the accurate and reliable data needed for evaluating project energy production potential and economics.

The second part of the wind energy assessment program underway involves regional wind resource analysis and mapping. This is an effort to assess overall wind potential in large areas of key provinces and to find good potential wind sites where wind measurement programs are needed. Preliminary wind assessment and mapping were conducted for two regions in southeastern China. The first region was the coastal area stretching from south eastern Guangdong up to northern Fujian. The second region was centered around the Poyang Lake in northern Jiangxi and included parts of two other provinces, Anhui and Hubei, extending from near Anqing southward to near Nanchang.

Using atmospheric flow models developed by the NREL, three regional wind maps, based on the Geographic Information System (GIS), have been developed. Terrain data in digital form was used in the modeling process. Wind and other meteorological data were combined into a very large database drawing from several sources. These databases included: information from 85 selected meteorological stations in the region; surface weather observations from World Meteorological Organization stations in southeastern China available through the National Climatic Data Center in the United States; marine data reported from ships at sea; near shore wind speed estimates derived from wave height measurement taken by satellites using microwave imaging; and from upper air data sets from rawinsonde instruments and pilot balloons.

Results from the wind mapping show many sites in the two study areas have good-to-excellent potential. The most productive sites were found along the coast and on offshore islands especially in Fujian. See Figure 9 [22]. Average annual wind speeds greater than 5.5 meters/second (m/s) are considered usable for wind power development. Many sites with much higher wind speeds have been found in the mapped area, although some of these sites are mountainous and may be difficult to develop due to steep terrain. Overall the study concluded that the coastal areas in Fujian and Guangdong, including off-shore islands and land up to 10 km inland, had wind resource potential of 47,388 MW.

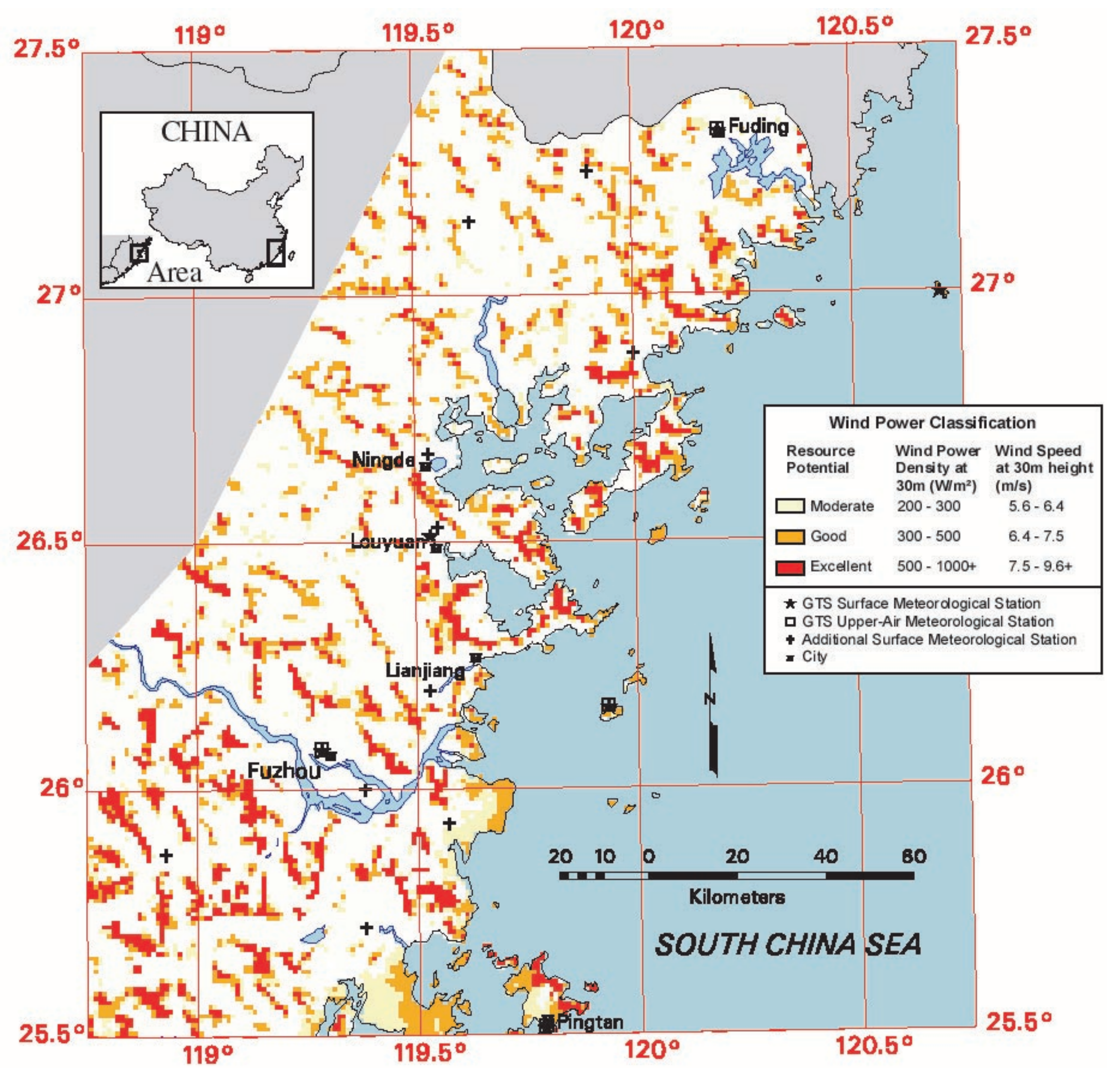

Figure 9. Regional wind resource mapping on Southeast China coast and estimates of average annual wind speed in standard wind power classes [22]

Wind mapping is also helping to identify the best locations for turbines at specific sites. One part of the study focused on Nanao Island in Guangdong province. This island, shown in Figure 10, was found to have many excellent wind sites and is the location of numerous wind power plant projects including one plant with ten 550-kW turbines supplied by the American company, Zond Energy Systems, Inc.

3.2.3 Grid Connected Wind Power Plant Analyses (Northeast Region Study)

One of the initial areas of cooperation was analyzing the economics and technical issues associated with integrating large-scale wind power plants into the existing grid network. Rising costs for other energy sources, declining costs for wind turbines, excellent regional wind resources, and the adaptability of the grid system to accommodate large-scale wind plants, making them an increasingly attractive option. This topic was the subject of a study completed in August 1997 by a visiting scientist from China's Electric Power Research Institute (EPRI - China) working at NREL for three months. Latest commercial computer models were used to evaluate integrating wind power into a section of the Northeast Regional grid in China. The northeast grid network studied is located in the Provinces of Heilongjaing, Jilin, and Liaoning with some connections to Inner Mongolia. See Figure 11.

The study focused on determining the value of installing significant amounts of wind power to the Northeast grid to determine economic costs and benefits. Results showed favorable economics, even at very low penetrations. An Electricity Financial Model (ELFIN) developed by the Environmental Defense Fund with support from the DOE, was used to compare the utility operating cost both with and without wind plants. Results from a partial study showed that by adding several thousand MW of wind plants that produced 1.5% of the regional energy, reducing emissions of NO_X 2.3%, SO_X 2.1% and CO_2 2.5%. The value of the wind energy was $0.042/kWh (0.34 RMB/kWh), with a resulting decrease in the marginal energy cost of 10.5% [23]. China EPRI has obtained a license to use the ELFIN model in China and is continuing this work. In addition, China EPRI plans to study effects on power quality and on grid system transient stability and control at higher penetration levels of wind power.

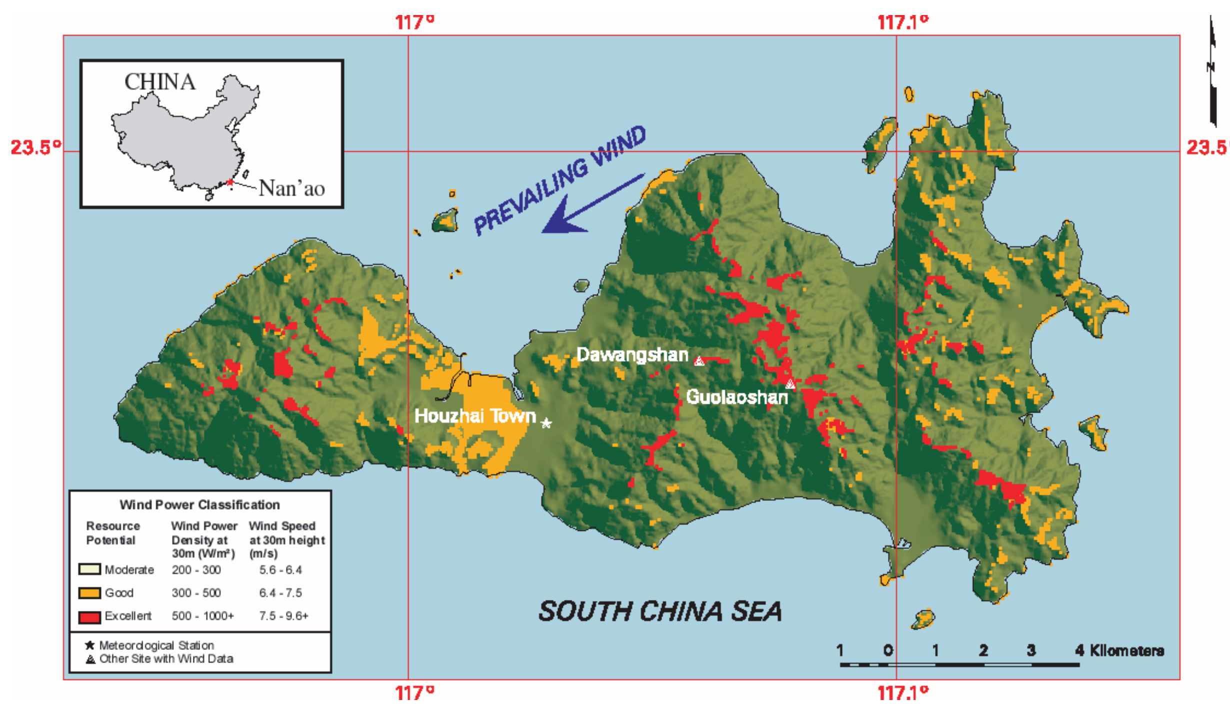

Figure 10. Wind site and digital terrain mapping of Nanao Island in Guangdong Province [22]

3.2.4 High Altitude Wind/PV Hybrid Tradeoff Study

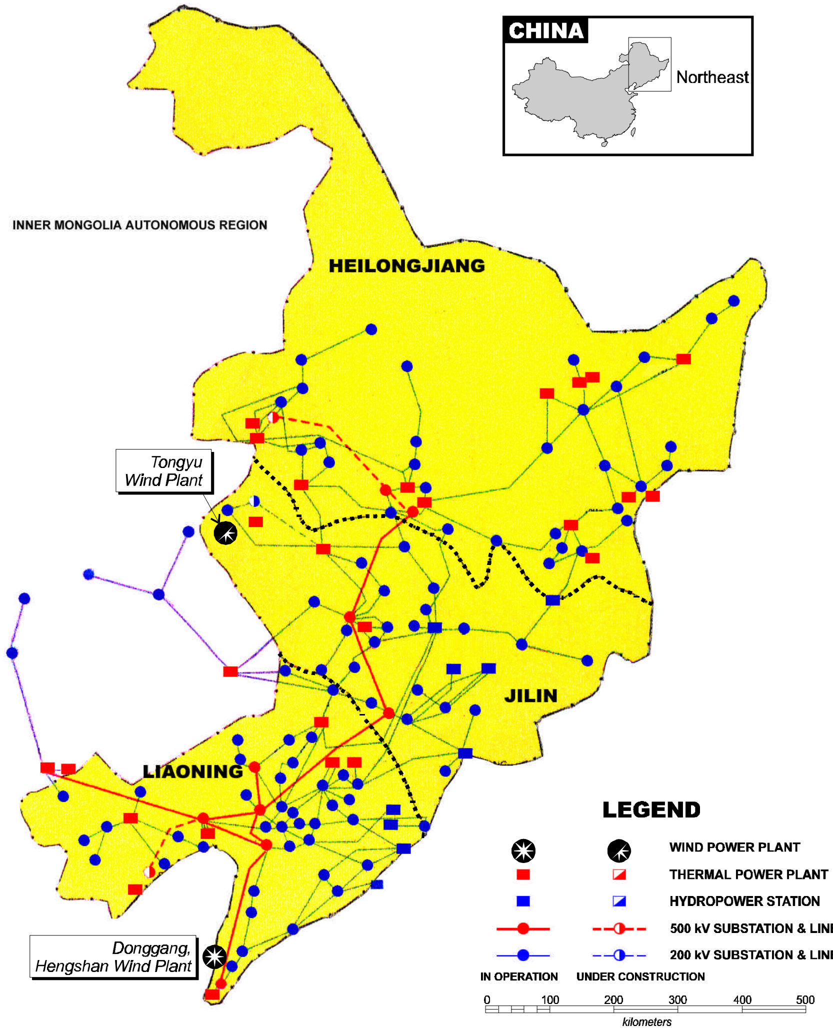

Figure 11. Schematic map of Northeast China power network and wind power plant sites [23]

An economic tradeoff study for various wind/PV hybrid systems for off-grid generation application at a high altitude site was carried out under the Annex II personnel exchange program. Three configuration options: wind/battery, wind/PV/battery, and PV/battery were studied for a village in Tibet. The village, Nace, located at 91° 30’ E and 31° 50’ N, is about 130 miles north of Lhasa, the Capitol of Tibet, in Ando County, Naqu District. Most people in this District are without any electricity. The average elevation of Naqu District is about 4,800 m (15,745 ft.). The annual average wind speed is 4–6 m/s and the annual average of 2,900 sunshine hours with an average temperature of -3°C (28°F). Nace village has 57 families and one school. The estimated daily loads are: five hours of 60 watts for TV and 20 watts lighting per family. Using the Hybrid-2 computer model developed at NWTC, the trade study indicated that the most economic system is wind/battery followed by wind/PV/battery. Despite a general concern about wind energy from the low air density at this high elevation, the relatively low cost of wind turbines makes them most economical in this application. The results were published on Acta Energiae Solaris Sinica (Quarterly), No. 3, Vol. 19, 1998 with the title, “The Optimization Design for 4-kW Wind/PV Hybrid Generating System in Tibet.”

3.2.5 Village Power Wind/Diesel Hybrid Pilot Project

In order to demonstrate the application of wind energy in medium scale off-grid applications, a pilot project, using U.S. turbines from Bergey Windpower, will be built on the island of Xiao Qing Dao in Shandong Province four nautical miles from Rushan City. SPCC choose the site as a typical island power system application, with good wind resources, easy access, and strong support from the locals, including the city of Rushan, the City Power Bureau, and the Island Council.

The island of Xiao Qing Dao has 346 inhabitants living in 123 homes that currently only have electricity available intermittently, which is typical of many island applications. The principal industries on the island are fishing and tourism. Power is produced by a 20-year-old, 13-kW diesel engine driven generator set, distributed through a local grid network at a cost of 3.0 RMB/kWh ($0.42/kWh). Electricity is used for street lighting and residential loads, including: lighting (50 watts), TV (80 watts), refrigerator (120 watts for 80 homes), washer (120 watts for 50 homes), and electric cooker (800 watts for 20 homes). Electricity is normally available 3-4 hours in the evening.

The planned wind/diesel pilot project will be installed during 1999. Current plans are to install four 10-kW wind turbines in a small wind power plant connected to a 30-kW diesel generator along with an inverter and battery bank. The turbines and other electronic equipment will be supplied by U.S. manufacturers (three turbines supplied by DOE and one by private industry). The Chinese will provide: turbine towers; foundations; electrical equipment; and operation, maintenance, and data collection support.

3.2.6 Workshop on Wind Plant and Business Development

A training workshop on Wind Power Business Development and Policy Analysis was held in Hangzhou, China on March 15-19, 1999 by Princeton Energy Resources International. The SPCC and the DOE sponsored the meeting that was hosted by the Zhejiang Provincial Power Bureau. Participants included 70 executives, planners, engineers, and economists from electric utilities, provincial and central government, local wind plant companies, and equipment manufacturers. Lectures covered topics on wind energy business trends and government run financial incentives employed worldwide, project debt and equity financing, cash flow planning and management, costs and economics of wind and other renewable energy technologies, and policy options needed to accelerate the deployment of wind plants in China. A case study was presented on financing 100-MW wind plants installed in China. Seven variations on the case study illustrated effects of wind speed, project scale, deployment experience and learning curves, tied-aid and Chinese tax laws, and special Bank of China financing terms. Representatives from Mees Pierson, a commercial Bank with offices in Shanghai, presented views on bankers' role and criteria for financing projects and equipment. Mees Pierson was selected because they had financed several large wind projects in the U.S.

3.3 Annex III – Energy Efficiency

Improving energy efficiency is a major component of China's energy development strategy. China is achieving great successes in improving energy efficiency, as evidenced by sustained rapid economic growth with relatively low energy consumption growth. During the years from 1980 to 1996, annual GDP increases averaged 10.1 percent, whereas annual energy consumption increases were only 5.35 percent. [24]

One measure of efficiency is called energy intensity, or the energy used to produce a unit of GDP. Over the past two decades China has been consuming more energy, but the GDP has been growing much faster. As a result since late 1970s, energy intensity in China has been declining at a rate of 4.5 percent per year. If energy intensity had not been reduced, the energy consumption today would be more than double. [25] (See figure 12.)

In the past, improving energy efficiency was employed simply for balancing energy supply and demand. Efficiency is now regarded as a means to strengthen competitiveness, reduce environment pollution, and achieve sustainable development. Although there has been some recent economic slowdown in China and throughout Asia, in the long term China's economy is expected to increase at moderately high rates for the foreseeable future; energy demand is also expected to increase, but at a slower and decreasing rate. Compared to most industrialized countries, China's energy efficiency is low, and potential of improving energy efficiency is still very large. Therefore, improving energy efficiency will continue to be a high priority area [26].

3.3.1 Technology and Application Descriptions

In terms of energy use per unit of GDP, China has one of the most energy-intensive economies in the world and China's industrial sector consumes more than two thirds of China's total energy. China's energy consumption is concentrated in industries such as chemicals, primary metals, cement, and pulp and paper – industries that are typically energy-intensive. In these industries, energy intensity is often compounded by inefficiencies resulting from other factors, such as the unavailability of efficient technologies; small plants that cannot attain economies of scale; and problems with maintenance of energy-efficient operations within plants [27]. Also, industry in China is highly dependent on the direct use of coal (70 percent).

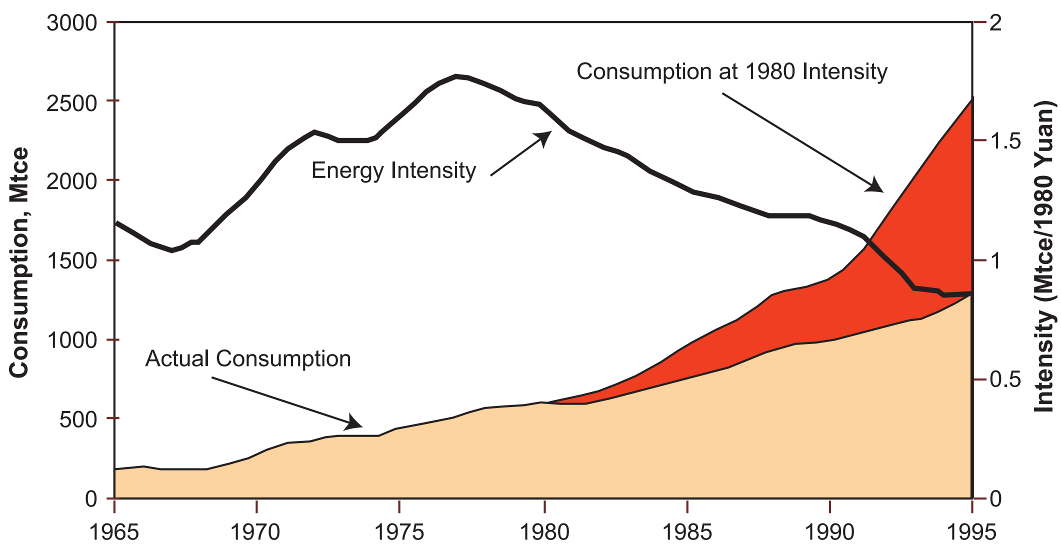

Figure 12. China's Energy Consumption and Energy Intensity, 1965 - 1997.
Sources: Pacific Northwest Laboratory, http://www.PNL.gov/China/engycons.htm [25]; and China Energy Databook, J.E. Sinton, et. al., Lawrence Berkeley National Labs, 1996; China Energy Annual Review, 1996, SETC, Beijing, China.

China's intent to improve energy efficiency, as evidenced by China's Agenda 21 Program and Ninth Five-Year Plan, creates opportunities for US-China cooperation:

- In the industrial area, opportunities include improved waste heat, gas, and waste steam recovery; expanded use of cogeneration; improved industrial furnaces and kilns; better monitoring and control systems; the use of improved insulation; and other renovations in thermal and steam systems. There is also an opportunity to install energy-efficient equipment such as boilers, electric motors, and motor systems, and associated electrical equipment.

- In the building sector, due to China's construction boom, substantial opportunities for improvement exist in new construction and retrofits, building envelopes, heating, ventilation and air conditioning systems and controls, and lighting systems.

- Appliance purchases are increasing, creating an opportunity to educate consumers about the advantages of buying energy-efficient products and providing a need for cooperation on energy-efficient codes and standards.

3.3.2 Areas of Cooperation

The US-China energy efficiency activities are conducted through teams with designated team leaders; the teams are composed of representatives from industry, state agencies, energy associations, the DOE national laboratories, and other interested parties. China has implemented a similar team arrangement. A steering committee was established to coordinate the US-China energy efficiency activities under the Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Technology Development and Utilization. The steering committee is chaired jointly by Mr. Li Hong Xun of the State Development and Planning Commission and Ms. Denise Swink of the DOE. The committee consists of representatives of the State Planning and Development Commission, the DOE, and China and U.S. team leaders. On May 5-7, 1997, the first US-China Energy Efficiency Steering Committee Meeting was held in Beijing. Annex III, signed in October 1996, covers energy efficiency activities in energy policy, information exchange and business outreach, district heating, cogeneration, energy-efficient buildings, energy-efficient motors systems, industrial process controls, lighting, amorphous core transformers, and finance. A summary of the actions and accomplishments, as of October 1998, in each of the ten areas follows.

3.3.2.1 Energy Policy – The goal of the activity is to collaborate on policies to promote energy efficiency. After documenting ongoing U.S.-China energy policy collaborations, emphasis was placed on (1) assessing the applicability of U.S. energy policy to China, and (2) assisting in standards development in China.

In July 1997, DOE's Policy Office sent an extensive list of information on laws, regulations, and policy implementation to the State Planning Commission. On November 1, 1997, the National People's Congress passed the Law on Energy Conservation of the People's Republic of China, which took effect on January 1, 1998. Subsequently, a U.S. delegation visited China to participate in a workshop on energy efficiency policy. Held on December 11-12, 1997, in Beijing, the workshop featured discussions about implementation of U.S. energy efficiency laws and policies at the Federal and state levels. The U.S. delegation included representatives from the Natural Resources Defense Council, the Alliance to Save Energy, the American Council for an Energy-Efficient Economy, California Energy Commission, Lawrence Berkeley National Laboratory, and the DOE.

Collaboration is also underway to develop guidelines and standards for key products, refrigerators, air conditioners, ballasts, and fluorescent lamps. The China State Bureau of Technical Supervision is promulgating energy efficiency standards. Standards for refrigerators were established in 1997 and standards for fluorescent lamps began in 1998; standards for air conditioners are due in 1999. To assist in creating refrigerator energy efficiency standards, Lawrence Berkeley National Laboratory trained three visiting Chinese in the use of energy efficiency analysis tools, during June 1996.

3.3.2.2 Information Exchange and Business Outreach – The information exchange activity acts as a focal point for information collection and dissemination of information on Chinese energy efficiency issues. Information is disseminated on technologies, market conditions, and other topics of interest. World Wide Web sites for China information created at Pacific Northwest National Laboratory (www.pnl.gov/china) and the Beijing Energy Conservation Institute (BECon) (www.gcinfo.com/BECon) include: technical papers; newsletters; links to other sites; and statistics on China's energy, environment, and economy. A monthly China EE Info newsletter is also posted on these web sites. In response to questions posed by U.S. firms about China's electricity sector, Pacific Northwest National Laboratory, BECon, and China's Energy Research Institute jointly published a comprehensive report on China's electricity options in June 1998 [25]. The report is available on Pacific Northwest National Laboratory's web site.

3.3.2.3 Energy-Efficient Electric Motor Systems – The U.S. and China are working to facilitate the development, commercialization, and use in China of high-efficiency motors, motor speed controls, and other technologies and practices to improve motor system efficiency. A study of the Chinese motor market, funded by the DOE, was conducted by the American Council for an Energy-Efficient Economy in conjunction with the Beijing Energy Conservation Institute and the Shanghai Electric Apparatus Institute. The published study is available from the American Council for an Energy-Efficient Economy. In addition, the U.S. team has provided data on motors, programs, and products to China and is helping U.S. motor manufacturers assess opportunities for joint ventures in China.

Efforts are now focused on developing and conducting a Chinese Motor Challenge Program based on the successful DOE motor program. As part of the activity, data is being exchanged on motor systems, including fans, compressors, and pump systems. Discussions with the China Energy Conservation Investment Corporation in December 1997 resulted in an agreement to hold a Motor Challenge workshop in Beijing in May 1998. The U.S. delegation included representatives from the American Council for an Energy-Efficient Economy, Lawrence Berkeley National Laboratory, and U.S. industry. Following the workshop, the U.S. drafted a revised action plan for a China Motor System Energy Conservation Program. The China Energy Conservation Investment Corporation reviewed the plan, which includes background information, program goals, and program plans for the short, medium, and long-terms. The project's goal is to establish a major national program beginning in one province thus providing a laboratory to test concepts for the national program. Funding for this program is being sought.

3.3.2.4 District Heating – As part of the district heating plan to implement retrofits in five district heating sites in China, heat meters were installed in two Yantai apartment buildings and thermal regulating valves were installed in one. Started in November 1997, the demonstration project was completed in spring 1998. Relative energy use and savings, as well as residents' comfort, are being assessed. An evaluation report will be released in the near future pending

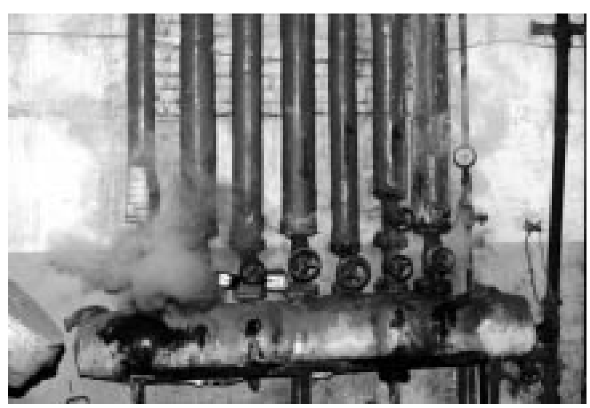

Figure 13. District Heating Project in Beijing

completion of discussions with China's Ministry of Construction. The Ministry of Construction is considering extending the project to the entire Yantai district heating system. A workshop to disseminate the demonstration's results to a broad Chinese audience is being considered.

3.3.2.5 Cogeneration – The objective of the cogeneration activity is to promote cogeneration projects in China with U.S. investors and partners. As part of this activity, a June 1996 U.S.-China Cogeneration Experts' Seminar in Washington, D.C., was organized by the China Energy Conservation Investment Corporation, Energy Resources International, and Lawrence Berkeley National Laboratory. Key Chinese cogeneration developers and policy staff met with interested U.S. private sector partners and presented information on proposed cogeneration projects open to U.S. investment.

The China Energy Conservation Investment Corporation prepared documents describing cogeneration in China, the approval process for cogeneration projects, and related policies. Because of the large economic changes that have taken place, these documents now need to be revised. To reduce the transaction costs of cogeneration projects in China, the U.S. team drafted model documents for power purchases, steam sales, and joint venture agreements. In July 1998, the U.S. team provided Chinese and English versions to the Chinese Energy Conservation Investment Corporation, who distributed them to national and local-level stakeholders. The Chinese Energy Conservation Investment Corporation consolidated comments and plans to use the documents as models for all cogeneration projects in China.

3.3.2.6 Energy-Efficient Buildings – In January 1998, an action plan was completed. The plan recognizes the need to improve mutual understanding of the building industry in the U.S. and China and to recognize the applicability of U.S. energy-efficient building technologies in China. China and the U.S. are planning two workshops. The first workshop was held in November 1999 in the U.S., and will be followed by one in China. To assist with preliminary planning, the DOE's Office of Building Technologies is sponsoring a visit by two Chinese researchers to work at Lawrence Berkeley National Laboratory. The researchers, Professor Tu Fengxang (China Building Energy Conservation Association) and Liu Jianping (China Energy Conservation Investment Corporation) will prepare background information and assist in organizing the workshops.

3.3.2.7 Energy-Efficient Lighting – China's Green Lights Program is one of the major energy conservation programs in the Ninth Five-Year Plan. As part of this program, China is working to increase the quantity and quality of high-efficiency lighting products and to promote efficient products. The lighting plan will assist the Green Lights Program in several activities: training, product certification and labeling, lighting standards, public information, and facilitating joint ventures.

Figure 14. Energy Efficient lamps are manufactured in China and are widely used to save electricity

In Summer 1997, a Chinese Green Lights team, sponsored by a United Nations Development Program project, visited U.S. manufacturers and Lawrence Berkeley National Laboratory and U.S. experts presented lectures at an annual Green Lights conference in Beijing. In addition, a delegation from the State Bureau of Technical Supervision visited Lawrence Berkeley National Laboratory in Fall 1997 to work on developing a product testing, a certification, and labeling program. In May 1998, a decision was made to pursue a Global Environmental Facility grant that will broaden the prior China Green Lights program into a national effort. Key program elements are: continuation of product certification and labeling program; improved quality of efficient lighting products; facilitation of bulk purchases; development and implementation of education, promotional, and finance programs; development of design and product standards; and documentation of market trends.

3.3.2.8 Amorphous Core Transformers – Amorphous metal is a new material used in transformer cores, that lowers energy losses in devices used for raising and lowering electric power voltages. The goal of the amorphous metal transformer activity is to raise the design and manufacturing level of amorphous metal cores and transformers in China and promote the application of amorphous metal distribution transformers, thereby reducing energy loss and increasing energy efficiency. Cost reduction is important and Allied Signal, the U.S. team leader, has been working with Chinese transformer manufacturers to reduce price premiums for amorphous metal transformers from 70 percent in 1995 to 25 percent in 1997, with a target of less than 20 percent after 1999.

In January 1998, the State Planning Commission issued a letter outlining the steps that it will take to promote the production of amorphous metal transformers on a widespread basis in China. In May 1998, Allied Signal and General Electric (GE) concluded an agreement with Shanghai Zhixin Company to license GE's amorphous metal technology. Construction of a plant is underway and start-up is expected during 1999. Until then, Zhixin is importing finished transformers from GE and plans to purchase amorphous cores from Allied Signal's plant in Pudong. With completion of the new plant, the price premium goal of less than 20 percent will be met.

3.3.2.9 Industrial Process Controls – The objective of this activity is to implement process improvements in at least nine different industrial firms in China. The plan calls for the identification of candidates for process improvements in at least three plant facilities, within three process industries. Subsequently, participants would conduct workshops, site visits, and contract negotiations to implement the installations of advanced process control technologies. Current efforts focus on how to fund the evaluations that are required to implement the plan.

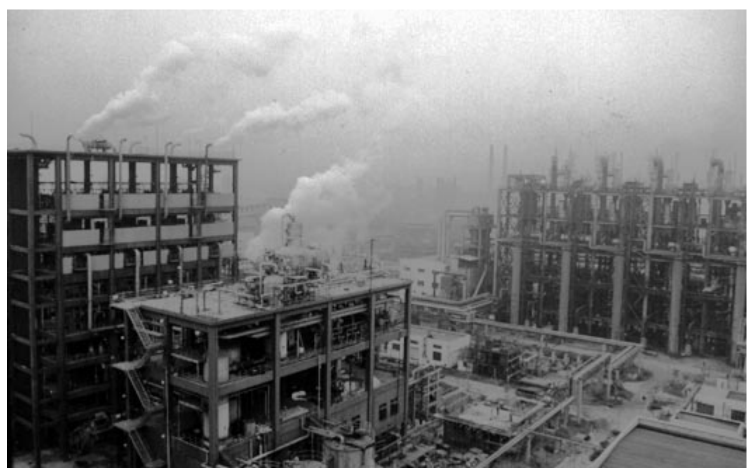

Figure 15. Coking and chemical plant in Shanghai – Industrial process control can substantially improve operating efficiency in many industrial plants

3.3.2.10 Finance – The objective of the finance activity is to identify constraints to energy efficiency finance in China, and recommend options for energy efficiency financing. The team will address three key issues: (1) transparency in companies – by identifying the parties with authority to implement contracts and projects; (2) security – by providing repayment guarantees and financial; and (3) initial project support – by finding local sources of support for feasibility studies and other initial project costs.

In May 1997, Pacific Northwest National Laboratory hosted a representative of the China Energy Conservation Investment Corporation to work on financial issues and potential future joint cooperation. The U.S. team is continuing efforts to identify and finance energy efficiency projects. Efforts by the China Energy Conservation Investment Corporation to produce a guide book for U.S. companies on the project approval process in China have been put in abeyance until the reform process is closer to completion.

3.4 Annex IV – Renewable Energy Business Development

The DOE and the SETC signed the Annex IV Agreement, Renewable Energy Business Development, on October 25, 1996. The Chinese Center for Renewable Energy Development (CRED) is implementing or coordinating most of the activities under this Annex that are designed to encourage collaboration between Chinese and American industrial partners. The goals are to promote energy conservation and efficiency business development and to increase the use of renewable energy in China. To date, activities have included assistance on energy policy analysis, exchange of technical information, and business and professional training. These activities focused on relationship building, project identification, and providing access to available project financing.

There have been increasing business activities between American and Chinese firms since the Agreement was signed. Several trade missions have been conducted, both to China and to the U.S., involving leaders from industry and government in both countries. In 1998, the first U.S.-China industrial joint venture agreement on renewable energy was developed between, Oklahoma based, Bergey Windpower Company and Xiangtan Electric Generator Co., to produce and sell 10-kW wind turbines in China. They plan to produce 300 units annually in China to meet the rapidly growing demand and perhaps to supply China's "Brightness Program" for rural electrification, sponsored by the SDPC.

China has taken a variety of steps to encourage renewable energy business development. For example, import duty and taxes have been reduced or eliminated on some products. Since January 1, 1998, import duty was eliminated on wind turbines larger than 300 kW and the import duty on smaller turbines is 12 percent. There is also special tax treatment for projects qualified as "high technology," which would include wind, solar, and other renewable technologies. For industries or joint ventures registered in a "High Technology Development Zone," there is an exemption from income tax (typically 33 percent) for two years and reduced to half for three additional years. In addition, MOST and SDPC issued a special notice "Supporting the Development of Renewable Energy," encouraging domestic banks to give priority to construction of renewable energy projects, allowing 2 percent financing interest discount on loans, and providing other financial incentives [28].

3.4.1 Provincial Business Development Studies

Two business development studies have been performed under the sponsorship of the DOE in cooperation with CRED. Data was collected on renewable energy resource potential, local government and industrial interest in renewable technologies, procedures and rules controlling project implementation, and other factors that could influence the deployment of renewable energy either positively or negatively. The first study, conducted in late 1996, covered market potential in six provinces: Gansu, Inner Mongolia, Qinghai, Shandong, Xinjiang, and Zhejiang. The second study, conducted in June 1998, covered four additional provinces, Guangdong, Jiangxi, Jilin, and Yunnan, and addressed the changes that have occurred as a result of the restructuring in the central and regional governments. The resulting reports provided market information that could be useful for American companies considering entering China's renewable energy market.

One of the salient points of these studies related to the influence of tied-aid and subsidized loan programs provided by several European countries. The reports found that U.S. wind companies would have a difficult time competing with European firms on small projects. However, most of the tied-aid is limited to projects smaller than $30 million and the U.S. Export-Import Bank can provide U.S. companies with loan terms and conditions that match the tied-aid offers from competitors. This matching aid has been employed on three wind power plant projects, each with ten 550-kW wind turbines built by the California company Zond Energy Systems, but this process is considered by industry to be a slower and more complicated than the European tied-aid approach. Tied-aid may be less important in the future, once larger renewable energy projects are undertaken, commercial or international bank financing and open competition will likely be used.

3.4.2 Support for World Bank and other Multilateral Programs

The DOE, through NREL has supported activities of the United Nations Development Programme, the World Bank, and other multilateral institutions in China. In addition, the DOE has worked with U.S. renewable energy and energy efficiency industries, in their efforts to promote renewable energy and conservation as viable investment opportunities.

The DOE provided technical assistance, economic analysis, and wind resource assessments to the United Nations Development Programme and to the World Bank in support of their initiatives for renewable energy development in China. In one of the supported studies, the World Bank concluded that, "Provided certain policy and institutional constraints are removed, the study indicates that three technologies are ready for efforts aimed at large-scale market development of: grid-connected windfarms; solar PV, especially solar home systems; and bagasse cogeneration" [11]. The DOE and NREL technical assistance helped the World Bank to develop a renewable project, involving more than $400 million in loans, now underway in China. In addition, the United Nations Development Programme is carrying out a $26 million renewable energy program.

3.4.3 Business Development Mechanisms and Incentives

The U.S. Export-Import Bank has offered China a $100 million renewable energy credit facility. The amount of available financing was initially $50 million in secured loans. This was later expanded to $100 million and can be used for U.S. goods and services for a full range of renewable energy projects and for development of energy efficient technologies. Projects eligible for the loans include: wind, solar, waste fired cogeneration, geothermal technologies, bagasse fired plants, energy efficient building modifications, electric motor upgrade to more efficient designs, and other clean energy technologies. Applicants may apply for either direct loans or for loan guarantees. Repayment terms, debt coverage, and interest rates will be the best possible, within the guidelines of the Organization for Economic Cooperation and Development (OECD).

3.4.4 Training on Project Development and Financing

Four people from the CRED participated in a series of training programs sponsored by NREL in the U.S. from June through September 1998. These training activities were designed to support capacity building in China through institutional participation in the programs for advanced development of project siting analysis capability, use of realistic economic analytical methods in project evaluation and development, and to transfer of U.S. experience in renewable energy policy development to China to encourage and accelerate similar efforts there. The training activities consisted of: (1) training in Geographical Information System (GIS) software support and analysis in partnership with Environmental Systems Research Institute, Inc. in Boulder, Colorado (ESRI), (2) life cycle cost analysis, and (3) U.S. renewable energy policy development and analysis to support commercialization of renewable technologies in the U.S.

In April 1999, SPCC organized and DOE conducted a workshop on "How to accelerate China's windpower development" described in detail in Section 3.2.6 of this report. The U.S. firm, Princeton Energy Resources

International, conducted the three-day workshop titled, “Wind Energy Business Development and Policy Analysis,” for 70 people selected by SPCC from their offices in Beijing, from regional power bureaus, provincial planning commissions, and private companies in the wind business. The goal of the training was to provide the participants with knowledge on key business aspects of developing large-scale wind plants, by drawing on the experience in the U.S. of installing more than 2,000 MW of wind plants. Topics discussed included: renewable energy financial incentives, wind power plant economic analysis, project financing and contracting, and factors affecting costs, in an effort to accelerate the development and deployment of renewable energy technologies, especially wind, in China.

Another training program supported by the DOE, allowed participation of five key people from the SPCC, electric power institutes, provincial power bureaus, and region planning commissions to participate in the annual Wind Energy Applications Training Symposiums in 1996 and 1997. The American Wind Energy Association organized these two-week training programs with funding from the DOE and other U.S. government agencies. The intensive symposium covered all aspects of wind installation development, financing, and operation in a full range of grid-connected and off-grid applications.

3.4.5 PV Industry Survey and Opportunities Report

During September and October 1998, U.S.-based, Sherring Energy Associates conducted a 40-day mission to more than 11 cities in seven provinces in China. The mission was designed to investigate first hand, the status of the PV industry, applications, and markets in China and to evaluate business opportunities for U.S. companies in China. Assistance to the mission was provided by the CRED. A report was generated, titled “CHINA PV Business and Application Evaluation,” which is to be published by NREL in 1999.

The China PV report provides profiles and contact information for more than 20 PV companies operating in China in module and balance-of-system component manufacturing, system integration, and application development. An assessment is provided of the current status of the PV industry and market development in China, the current barriers to sustainable growth of PV markets, and recommendations for pursuing business in China. The report also provides some information on other domestic and international projects being developed in China using PV technology.

The study concludes that China’s solar photovoltaic production industry is growing rapidly, but is facing significant technical challenges. Specific conclusions are that: (1) There is a ready cash market for tens of thousands of solar home systems annually, (2) there are needs for improved equipment to mass produce cells, unified product specifications, and quality control standards for cells and other system components including charge controllers, (3) emphasis on “least cost” is resulting in low quality products, and (4) needs for demonstration programs to gain knowledge and experience at the provincial level.

3.4.6 PV Background Report

The CRED has prepared a report titled “Commercialization of Solar PV Systems in China,” which is scheduled for publication as a bilingual report in 1999. The report provides a detailed overview of the various market sectors and applications for PV in China, including a historical overview of PV development in China. The report and study complement the PV industry survey report that was discussed in section 3.4.5. The report also provides specific information on companies in China which have qualified for participation in the rural electrification projects which will be supported by the World Bank.

3.5 Annex V – Electric and Hybrid-Electric Vehicle Development

The automotive industry is one of the main industries in China and is expanding rapidly. Because of its importance to the domestic economy, the auto industry receives support from the Central Government. The government support emphasizes both production capacity increases and product quality improvement. As a result, car production capacity is expected to reach 1.2 million units in 2000 and triple that by 2010. On the other hand, increasing the number of automobiles will aggravate the environmental and energy problems of China. Motor vehicles are a major source of air pollution in major Chinese cities, and their contribution is increasing. In Beijing, for example, mobile sources accounted for 39% of the carbon monoxide, 75% of the hydrocarbons, and 46% of the nitrogen oxide emissions in 1989 [19]. Since then the motor vehicle use and traffic congestion have increased, prompting the government to focus attention on the research and development of electric vehicles (EV) and hybrid-electric vehicle technologies.

Annex V to the Protocol Agreement, titled "Electric Vehicle and Hybrid-Electric Vehicle Development," was signed on November 18, 1997. Initial meetings were held in December 1997 in Washington, D.C.; the U.S. Annex V Team visited Beijing in early August 1998, held further discussions with representatives of the Ministry of Science and Technology, and visited electric vehicle research facilities and automotive manufacturing facilities in China. At these sessions both sides agreed to emphasize information exchange in four major areas:

- Technology Transfer: Coordination on basic public domain technology with emphasis on standards development and testing methods. The emphasis is on creating a high level of technical excellence and autonomy in the Chinese advanced vehicle technology programs. U. S. experience shows the importance of these activities to a sound program.

- Implementation: Coordination on basic implementation policy and practice issues. U. S. experience in conducting accelerated implementation programs will be applied as appropriate to the rapidly developing Chinese vehicle market. New forums will broaden the exchange of information and ideas needed to accelerate the development, manufacture, and deployment of advanced technology vehicles in China.

- Environmental Protection: Coordination on the basic elements of deploying advanced technology vehicles in an environmentally acceptable manner. This includes assuring that the Chinese government and industry take appropriate measures to implement safe transportation, in-vehicle use, and recycling or reclamation of advanced technology components and subsystems.

- Development of Small Business Opportunities: Coordination on developing opportunities for small businesses to work with the Chinese automotive industries on critical technology needs for advanced vehicles. Small business opportunities will be created through a variety of mechanisms, such as small business set-asides, similar to those already established in the United States.

The U.S. Annex V Team recognized the ambitious nature of the Chinese program and the many technical and political issues. Both sides agree on the overall need to make progress at a faster rate and encourage more industry involvement. Facilitating information exchange and private sector business activity is considered to be an appropriate role for the Team. Consequently, open workshops and demonstration projects are expected to be important tools used in the agreement. The overall U.S.-China program faces these same issues.

In technology transfer, opportunities will be sought for interchange of researchers or joint projects between Chinese and U. S. research laboratories. The interchanges are expected to emphasize advanced batteries and fuel cell technology. In 1999, web site development is planned to disseminate information on EV and hybrid-electric vehicles. Further emphasis will be sought on links between private businesses to conduct appropriate programs with Chinese government and business entities. Where appropriate, the DOE will work with Chinese institutions to seek international bank and development organizations' funding and other support for projects in China.

3.5.1 Technology Description and Background

China has been expanding development of its automotive industry in the transportation sector. This development includes the petroleum industry which supplies traditional transportation fuels such as gasoline and diesel fuel. However, there is increasing concern with the economic and environmental impacts of growing fossil fuel use, especially the increased use of imported fuels. In 1993, China became a net oil importer. Imports continue to grow in spite of efforts to employ enhanced oil recovery techniques to older fields and to develop offshore reserves in the South China Sea and promising new areas in western China – in particular the remote Tarim Basin in the Taklamakan Desert. New pipelines were completed to that site, next to another smaller, but less remote, area in the Turpan-Hami, or Tuha, Basin.

Air pollution from automobiles is an increasing problem in urban areas. Ambient hydrocarbons, carbon monoxide, and ozone concentrations in major cities exceed Chinese standards and are attributed primarily to mobile sources– especially automobiles. Although the number of vehicles in Beijing is only one-tenth of that in Los Angeles and Tokyo, vehicle emissions are about the same for all three cities [1,19].

China's automotive sector is considered a 'pillar industry,' part of the centrally planned economy. The sale, servicing, and use of automotive vehicles for transporting people and goods is increasingly in the private sector. Automotive manufacturers are shifting emphasis away from production of heavy trucks and buses, these being about 65 percent of the total fleet in 1990. Light duty personal vehicles, especially privately owned passenger vehicles, are the fastest growing segment with this segment of the fleet more than doubling from 1990 to 1995 compared to the prior five year period. See Table 4.

International business development is expanding in the automotive sector. Under joint ventures with American, European, and Japanese firms, new manufacturing and assembly plants are now operating in China. General Motors was one of the companies invited to build an automotive assembly plant in China (for small Buicks). Chrysler, through a joint venture in the Beijing Jeep Factory, is currently producing about 100,000 vehicles with more than 80% of the components manufactured in China.

Figure 16. Traffic congestion and air pollution in Beijing

Research on electric and hybrid-electric (and alternative fuel) vehicles is an area of expanding interest in China. In 1996, the EV project became one of the National Science and Technology Projects. Currently, part of the research

Table 4. Registered Civilian Vehicle Fleet is Growing Quickly

Type of Vehicle/Owner	1985	1990 (thousands)	1995	Average annual growth 1985-95 (percent)
Passenger vehicles	795	1,622	4,179	18
Professional Transport	83	108	131	5
Privately Owned	19	241	786	45
Trucks	2,232	3,685	5,854	10
Professional Transport	194	198	142	-3
Privately Owned	265	573	1,226	17
Other	616	411	1,227	7
Total	3,643	5,718	11,260	13

Sources: World Bank and China statistical Yearbook 1996.

program is focused on Lithium-Ion and Nickel-Metal-Hydride batteries and on fuel cells. EV testing and demonstration areas have been established in Shantou-Nanao and seventeen EVs have been tested for two years. The integrating design of the prototype EV is continuing and there have been some important achievements in the design of key parts. According to the plan, the Electric Concept Vehicle will be completed and demonstrated in 2000.

Currently, an economic evaluation of developing Hybrid EV technology is under way, to ensure the resulting concepts are practical. As low-pollution or no-pollution vehicles, EVs are expected to be the important transportation tool in the 21st century. China plans to attract the world's advanced technology and deploy some new vehicle technology in creative ways.

3.5.2 Work Plans Under Development

Several technical discussion meetings have been held in the U.S. and China in an effort to develop work plans. In 1998, a DOE/industry delegation visited electric vehicle research facilities at Tsinghua University and the Chinese Academy of Science. This delegation also visited the Beijing Jeep plant, and met with MOST and the multi-organizational electric vehicle team. Areas for cooperation were discussed. The areas of possible cooperation focused on the following topics:

Battery Management and State-of-Charge Controllers–Tsinghua University, Delphi-Automotive Institute, provides broad interdisciplinary technical training in management skills needed for a modern automotive industry. The University's Departments of Automotive Engineering and Computer Science and Technology have produced a number of converted electric vehicles, including an electric bike, a 4-

Figure 17. Chevrolet S-10 electric vehicle in commercial demonstration program in China

passenger electric car, and a 16-passenger electric bus using DC motors, DC controllers, and flooded (tubular) lead acid batteries. Also, joint work is being done with General Motors in the U.S. on battery management systems and state-of-charge indicators.

AC Motor Control Systems – Chinese Academy of Sciences, Institute for Electrical Engineering is developing AC motor control systems for use in the Chinese electric vehicles in the 50 kW range. The research group is examining different motor types: induction motors, permanent magnet synchronous motors, and switched reluctance motors. This could lead to joint venture opportunities to produce the power switches or micro controller chips.

Standards Development – China is working on standards development in four areas: overall vehicle systems, controllers and motors, batteries, and battery charging. This is very similar to the approach used in the U.S. by the Society of Automotive Engineers, and industry in both U.S. and China can benefit from mutually compatible standards.

Electrochemical Technology on Batteries and Fuel Cells – China is working on a number of advanced electrochemical technologies that are also being developed in the U.S. This includes work on nickel metal hydride and lithium ion batteries for electric vehicles and possibly on proton exchange membrane fuel cells. Possible assignments and exchange of scientific personnel between National Laboratories in both countries is being discussed.

Technology Transfer – The technology transfer areas represent agreements that came out of the first meeting under Annex V in December 1997. These areas were:

1. Organization of current U.S. Federal Government programs – DOE provided general information for use in structuring Chinese electric vehicle programs.
2. Fast charging – DOE provided a general technical information report on this topic based on work completed in this area by the U.S. firms AeroVironment and Norvick.
3. AC motor controllers – DOE provided general reports about the status of AC motor controllers in the U.S. and encouraged possible cooperation with U.S. small businesses in this field including: Unique Mobility and AC Propulsion.

Implementation – The U.S. team is providing technical assistance in planning the implementation and management processes. Prior work was reviewed, including the 1995 study “Encouraging Purchase and Use of Electric Motor Vehicles” and the 1997 “Electric Utility Participation Study.” Other major U.S. implementation programs, including Clean Cities and the Electric Vehicle Ready Cities program were also reviewed. China is considering doing similar studies and implementation programs.

Environmental Protection – Both countries are concerned about avoiding the possibilities of creating new or unexpected environmental problems as a result of introducing new vehicle technologies. Cooperation can be beneficial to insuring that all important environmental issues are considered. One area of cooperation is on environmental assessments which were done for advanced batteries by the NREL, as well as, the ongoing work of the Advanced Battery Readiness Working Groups and the Infrastructure Working Council. Cooperation could lead to Chinese participation in appropriate international working groups on international standards for abuse testing and other topics relating to advanced batteries.

Small Business Roles – There is interest in possible participation by United States small businesses in planning China’s electric vehicle program.

3.6 Annex VI – Geothermal Energy Production and Use

Geothermal energy sources are of growing importance in China and have large potential, both for electric power production and for direct use for heating or cooling. The U.S. has developed leading geothermal technology and strong industrial interest in these areas. As a result, Annex VI to the Protocol on Cooperative Activities on Geothermal Production and Use, was signed on November 18, 1997 between the State Science and Technology Commission (now MOST) and the DOE. The objective of this agreement is to accelerate the utilization of geothermal resources in China, both for electricity generation and for direct thermal energy use. Forms of cooperation described in the Agreement include: planning and analysis of geothermal applications and resources, and scientific exchanges and visits.

China is a global leader and has rich geothermal resources with a long history of utilization in the use of geothermal resources for direct applications, with a thermal power contribution of more than 2,000 MW_{th} and a thermal energy production of more than 5,000 GWh in 1990 [5]. Hot springs have been used for space heating and for treatment of disease since the Ming Dynasty. Today there are 1,620 sites throughout China where geothermal energy is in direct use today [29]. In total, they have produced energy which is equivalent to burning 5 million tons of standard coal. Sites in operation include: 112 places for agricultural uses, 51 industrial applications, 65 sites using thermal springs for tourism, and 35 seismic observation stations.

Geothermal resources are spread widely across China. Evidence of abundant geothermal resources is widely spread around the country, including 2,500 thermal springs and 270 geothermal fields. Preliminary estimates are that recoverable reserves of geothermal energy are equivalent to 4.6 X 1,011 tons of standard coal [2]. Most of the hot springs are located in the Provinces of Fujian, Yunnan, Sichuan, and the Xizang (Tibet) Autonomous Region. High temperature geothermal resources are concentrated along the Himalayan Belt, which is an extension of the Mediterranean Geothermal Belt, passing through southern Tibet, western Sichuan and Yunnan, turning south through Thailand. The part of the Belt in China is extensive, more than 2,800 km long and 200-400 km wide. One of the best geothermal resources was found at one of the sites in the Yangbajain Field in Tibet (Figure 18), with a geothermal fluid temperature of 329.8°C at a depth of 2,007 m [30]. This is a good indication of the excellent mid- to high-temperature geothermal resources in the region.

Figure 18. Geothermal well drilling for the 10- MW power plant in the Yangbajain Field in Tibet

3.6.1 Technology and Application Descriptions

Geothermal energy systems use the conductive heat loss from the earth's interior to make steam, hot water, or with another heat transfer working fluid for direct use, e.g., building space heating/cooling, or to drive turbines to generate electricity. These two different geothermal applications are described below.

Geothermal Electricity Production

For thousands of years, people have benefitted from hot springs and steam vents, using them for bathing, cooking, and heating. During this century, technological advances have made it possible and economically practical to locate and drill into hydrothermal reservoirs, pipe the steam or hot water to the surface, and use the heat directly for space heating, agriculture, and industrial processes or to drive steam turbines to convert the heat into electricity. The reservoir temperature dictates the energy conversion process and also a significant driver in the economics. Only the high temperature, >200°C (392°F), and moderate temperature in the range >100°C and <200°C (212°F/392°F) geothermal resources are adequate for commercial power generation.

The total installed geothermal electric generation capacity is up to 29 MW and expansion is planned. Deep well, high temperature sources are used to make steam that is used to generate electricity at several geothermal sites. The largest site is the Yangbajain Geothermal Power Plant, located 94 km northwest of Lhasa the capital of Xizang Province (Tibet Autonomous Region). This plant has a peak capacity of 25 MW and has been producing about 100 TWh of electricity annually since 1979, providing about 50 percent of the electricity for the Lhasa grid [29 and 32]. In Yunnan Province another power generation project is underway and the first stage of public bidding will soon expand the drilling in the Hot Sea geothermal field located near Tengchong.

Geothermal Heat Pumps

Geothermal heat pumps (GHP) are a cost effective, energy efficient, and environmentally friendly way of heating and cooling buildings. They use the earth's relatively constant soil temperature to provide efficient year round heating and cooling. GHPs exchange heat with the earth through a system of buried plastic pipes called a ground heat exchanger. See Figure 19. In the winter, fluid in the pipes extracts heat from the earth, and carries it through the system and into the building. In the summer, heat is pulled from the building, carried through the system and deposited in the cool earth. Fans located inside the building distribute the warmed or cooled air throughout the interior, much like an air conditioner. GHPs save money in both operating and in maintenance costs. More than 70 percent of the energy required for heating and cooling comes from the earth.

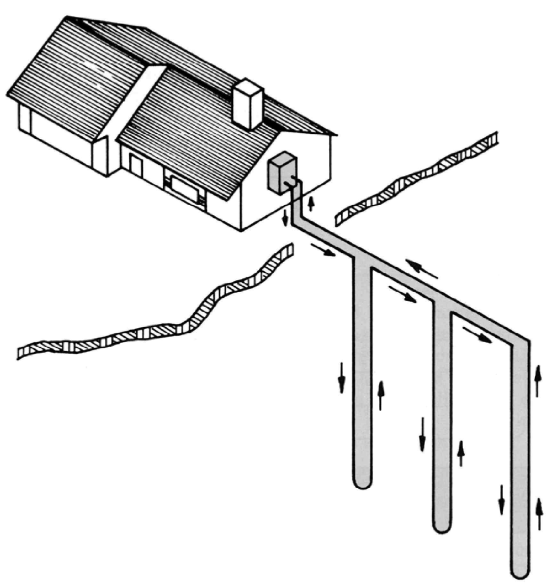

Figure 19. Schematic diagram of geothermal heat pump system for efficient building heating and cooling

Three geothermal heat pump demonstration projects are being developed to heat and cool buildings in Daqing (100,000 square meters), Shanghai (100,000 square meters), and Guangzhou (120,000 square meters), totaling 320,000 square meters (or 3.4 million square feet). Geothermal heat pump systems are likely to be economically attractive, energy efficient options, in virtually all of China. General agreements have been signed by three U.S. firms: Trane, Florida Heat, and Climate Master, to participate in these demonstration projects.

Geothermal Direct Use

China is also expanding the direct use of geothermal heat energy. Two demonstration sites have been established, one for building space heating and supplying hot water in Xiongxian County, Hebei Province and the other is for plantation crop growing and fish breeding in Rucheng County, Hunan Province.

3.6.2 Geothermal Heat Pump Application Feasibility Study

Geothermal heat pump technology as the broadest range of potential applications. The technical issues and economic considerations for the various applications and geographic regions are not well understood. Further, China has various climatic zones which would use different types of heat pump systems. In the northern, cold climatic areas with an average temperature of -10°C to -30°C (14°F to -22°F) in winter, geothermal heat pumps can be use to supplement or replace coal-fired heating boilers. In the central, warm climatic area, primarily the Changjiang valley, winter temperatures range from -5°C to 10°C (23°F to 50°F), and is severely hot in summer with the temperature from 30°C to 40°C (86°F to 106°F). In this area, dual-purpose geothermal heat pump air conditioner systems could be used. Southern, subtropical climatic areas, including Guangdong, Fujian, Hainan, Guangxi, and Hong Kong are very hot in summer, with air conditioning needed seven months per year and is mild in winter, not needing space heating.

Studies are underway on the technical and economic feasibility of using geothermal heat pumps in the three climatic zones. The U.S. is providing technical assistance to China for the three geothermal heat pump demonstration projects in China.

The proposed demonstrations will address different functions and market areas in China. The plan is to have one site in each climatic region. The planned demonstration sites are:

- A commercial building complex in the city of Daqing that is in the northern climatic region of China
- Commercial projects will demonstrate the technology in the central climatic region of China in Shanghai, including a multistory commercial office building , used as the Center of the Shanghai Minhang Economic and Technology Development Zone, which is fully air conditioned by a geothermal heat pump system, and
- A large apartment and commercial building complex near the city of Guangzhou that is in the southern climatic region of China.

As China intends to purchase U.S. built geothermal heat pump units, the DOE plans to support this major investment by helping industry to provide technical support and training. Assistance may include project feasibility studies, technical training, and educational and joint project evaluation and management activities.

In a second phase under consideration, the study could address technical feasibility of applying geothermal heat pump technology, focusing on shallow ground water resource distribution, deep geothermal resource distribution, and open water resource distribution. This study could also address the benefits and risks of applying geothermal heat pump technology to improve environmental quality in China.

3.6.3 Tengchong Geothermal Electric Power Pilot Plant

Responding to a request for technical assistance, DOE sent two U.S. geothermal experts to the Tengchong Geothermal Project in China to study drilling equipment, safety, and geological issues. The drilling expert reported that the drilling crew in Tengchong is very experienced in oil and gas well drilling to the projected depth, but they lack experience in geothermal drilling procedures. In some cases proper equipment, materials, and tools needed for this type of drilling were not available or were not being used correctly. Specific recommendations were made to the Chinese drilling team that should improve operational safety. It was also concluded that specialized drilling equipment was needed, is commercially available, and could significantly reduce the cost of drilling. The geothermal exploration expert reported that the site of current drilling may be too far away from the resource to have useful fluid temperature or flow rate. Suggestions were made for using other nearby sites with greater rock fracturing and expected higher temperature water that could be better commercial sites. To assist China in completing the first 10-MW geothermal pilot project at Tengchong, the U.S. experts recommend the following: (1) geologic and geophysical assistance; (2) drilling engineering assistance; (3) on-site training; (4) post drilling analysis; (5) development of future drilling plans. The long history of geothermal research and development and expertise available in the U.S. could be very beneficial to China's program and could create mutually beneficial business opportunities.

3.6.4 Geological Science Study

The DOE, through the Lawrence Berkeley Laboratory, is supporting a scientific study of the geological mechanisms that are producing the geothermal energy resources at the Tengchong site. By studying noble gas isotopes (argon, helium, neon, krypton, radon, and xenon) in rock samples from the well, it is possible to determine if the heat source is metamorphic or from volcanic magma flow near the surface. This information is important in continental motion studies and for predicting geothermal energy production potential.

4.0

Commercial Project Development and Financing

4.1 Energy and Environment Initiative

In October of 1997, a joint statement, the "Energy and Environment Cooperation Initiative," was signed with the goal of strengthening bilateral cooperation in order to help meet China's energy needs in a way which protects the local, regional and global environment. The Initiative focuses on energy and environmental science, technology development, and trade between the U.S. and China. Priority areas for cooperation identified in the Initiative are urban air quality, clean energy sources and energy efficiency, and rural electrification. An important goal of the Initiative is to find ways to encourage a greater role for the private sector in China's energy development, through encouraging programs which promote such investment and through continued policy, regulatory, and investment reforms. The Initiative supports the goals of the U.S.-China Forum on Environment and Development, co-chaired by Vice President Al Gore and Premier Zhu Rongji.

The Energy and Environment Initiative program includes: conducting research; sharing data; expanding the use of renewable energy resources, other clean energy technologies, and energy efficiency; and facilitating trade and investment in these technologies. The Initiative is also aimed at helping meet China's growing energy needs and rural electrification objectives with clean energy solutions. The areas targeted for cooperation are:

- Urban air quality - with government cooperation on energy related air pollution issues including: urban air quality monitoring, implementing emission standards, housing topics (building materials, home heating and cooking), reducing lead pollution, enhanced business sector involvement in natural gas infrastructure development, coal gasification, manufacture and use of fuel efficient vehicles, emissions monitoring equipment, and improved vehicle fuels.

- Rural electrification and energy sources - increasing involvement of industry and government to help bring clean energy to rural areas, using grid-connected, and off-grid renewable energy from wind, solar, hydro, and natural gas sources.

- Clean energy sources and energy efficiency - increasing involvement of industry and government to help development and use of energy efficient motors, cogeneration, industrial processes, lighting, district heating, power transformers and buildings; and to deploy clean energy technologies to fossil fuel fired systems and to develop large scale wind and solar energy systems.

Decisions on issues relating to global climate, the environment, and energy security affect the health, safety, and quality of life everywhere. The US-China Energy Efficiency and Renewable Energy Protocol provides a framework for cooperation to provide electricity to many people and to move toward a sustainable energy future. While the urgency of this effort maybe subject to debate, the long-term need to improve efficiency, shift from fossil fuel burning to hydrogen or other fuels, and using renewables energy wherever possible, are inevitable [34]. Actions taken under the Protocol can certainly help to accelerate the transition process [35].

4.2 EXIM Bank Clean Energy Program

The EXIM has much experience in financing private power projects in China. In addition, the EXIM Bank has authorized a $100 million in export credit to the Chinese government to finance the purchase of U. S. goods and services for projects involving renewable energy and energy efficient technologies. This credit facility was established by a Memorandum of Understanding for the Clean Energy Program, signed on March 29, 1999, by the SDPC, the DOE, the EXIM Bank, and the China Development Bank. Projects eligible for inclusion are: wind, solar, and geothermal technologies; industrial cogeneration; energy efficient buildings; and low NO_X and SO_X burners. Financing is available for commercial projects with competitive financing rates. Similar arrangements, where local banks assume the risk of the borrower, are being used in Brazil and Poland. This approach allows EXIM Bank to finance transactions where the borrower would otherwise be unable to secure commercial financing.

4.3 Conferences and Workshops

There have been several conferences and workshops co-sponsored by the MOST, the DOE, and other U.S. and Chinese government agencies. These meetings were designed to encourage private sector involvement in supporting China's goals for renewable energy use, efficiency improvement and sustainable development.

On September 22-23, 1998, the conference on Financing China's Energy Needs was co-sponsored in Beijing by the U.S. Department of Commerce, the DOE, and China's SDPC. This meeting brought together an array of U.S. firms involved in the development and financing of power projects, relevant organizations from China's national government, and quite significantly, representatives of many of China's provincial and regional power authorities. Response was also very strong from the American business community. The event was oversubscribed by both the U.S. private sector and the Chinese government and total participation topped 275 participants, including 175 company representatives. The conference was considered to be a success and a useful mechanism for business development.

5.0

Conclusions

During the four years since the U.S.-China Cooperation in the Fields of Energy Efficiency and Renewable Energy began, the DOE/MOST team has made substantial progress. Efforts are succeeding in developing the tools and business framework for China to demonstrate the technical and economic feasibility of using substantial renewable energy contributions and improving energy efficiency. These joint activities have contributed to successful demonstrations of solar-photovoltaic technology, wind turbines, biomass power plants, geothermal heat and power, and electric vehicles. There have also been numerous technical publications. These activities have resulted in immediate and possible long-term benefits to U.S. industry, including facilitation and establishment of new business partnerships, expansion of markets for American products, and purchase of some U.S. made equipment for the pilot projects in China. Several joint ventures between American and Chinese manufacturing companies have already been an indirect result. Overall activities have resulted in a strong multi-disciplinary U.S.-China team capable or addressing complex bilateral energy issues in mutually beneficial ways.

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References

1. China's Agenda 21, A White Paper on China's Population, Environment, and Development in the 21st Century, Chapter 13 on: Sustainable Energy Production and Consumption.
2. Institute of Scientific and Technical Information of China, New and Renewable Energy - Technologies and Production in China, Office of Chinese information Network of NRSE, Chongqing Branch, 1995.
3. World Bank, Clean Water, Blue Skies in China 2020 China's Environment in the New Century, September 1997.
4. U.S. Department of Energy, Energy Information Administration, China - Country Analysis Brief, www.eia.doe.gov/emeu/cabs/china.html, June 13, 1999.
5. U.S. Department of Energy, Energy Information Administration, Country Energy Profile: China, October 1997.
6. World Bank, China 2020 - Development Challenges in the New Century, September 1997.
7. John BYRNE, SHEN Bo, and William WALLACE, "The Economics of Sustainable Energy for Rural Development: A Study of Renewable Energy in Rural China," Energy Policy, Vol. 26, No. 1, pp. 45-54, 1998.
8. William WALLACE, TSUO Simon, Photovoltaics for Rural Electrification in the People's Republic of China, Proceedings of Institute of Electrical and Electronic Engineers, PV Specialists Conference, Anaheim, California, October 3, 1997.
9. Jack STONE, TSUO Simon, ULLAL H.S., et al., "PV Electrification in India and China: The NREL Experience in International Cooperation," Program Photovoltaic Research Applications, 6, 341-356 (1998).
10. John BYRNE, et al., Levelized Cost Analyses of Small-Scale, Off-Grid Photovoltaic, Wind, and PV-Wind Hybrid Systems for Inner Mongolia, China, Center for Energy and Environmental Policy, University of Delaware, Newark, Delaware, March, 1996. An updated report to be published.
11. Anil CABRAAL, et al, China Renewable Energy for Electric Power, September, World Bank Report No. 15592-CHA, 1996.
12. DAI Lin, LI Jingming, and Ralph OVEREND, Biomass Energy Conversion Technologies in China: Development and Assessment, China Environmental Science Press, ISBN 7-80135-552-0/X - 1335, Beijing, 1998.
13. L. SUN, Y. WANG, and Y. AN, Biomass Energy Conversion Technologies and Its Developing Environment in China, Proceedings of the World Energy Council Asia Pacific Regional Forum, pp. 165-177, Beijing, P.R.C., 1997.
14. DAI Lin, LI Jingming, and Ralph OVEREND, Assessment of Biomass Resource Availability in China, China Environmental Science Press, ISBN 7-80135-545-8/X - 1331, Beijing, 1998.
15. ZHANG Zhengmin, DENG Keyun, and Ralph OVEREND, Design for Market-Oriented Development Strategy of Bioenergy Technologies in China, China Environmental Science Press, ISBN 7-80135-756-6/X - 1400, Beijing, 1999.
16. Y. ZHAO and L. WU, Prospect of Technology and Development of Biogas Energy in China, Proceedings of the World Energy Council Asia Pacific Regional Forum, pp. 178-188, Beijing, P.R.C., 1997.

17. Z. SU, Z. HUANG, J. LI, Research on Availability of Excrement Resources on Large and Medium-Size Domestic Animal Farms in China, Biomass and Bioenergy in China in 1998, NREL Report NREL/SR-570-24860, July 1998.
18. Ministry of Agriculture, P.R.C., U.S. DOE, The Development and Assessment of Biomass Energy Conversion Technology in China, NREL Report NREL/SR-570-25146, July 1998.
19. M. WALSH, Motor Vehicle Pollution Control in China: An Urban Challenge, China's Urban Transportation Strategy, S. STARES and Z. LIU eds., World Bank 1996.
20. YIN Lian, Greeting Chinese Solar Energy and Wind Energy Time of 21st Century, Workshop on Wind Power Plant Business Development and Policy Analysis, Sponsored by State Power Corporation of China, China Fulin Windpower Development Corporation, and U.S. Department of Energy, Hangzhou, China, 15-19 March 1999.
21. SHI Pengfei, Potential Market of Wind Farm(s) in China, Proceedings of the American Wind Energy Association Windpower Conference, Denver Colorado, June 23-27, 1996.
22. D. ELLIOTT, M. SCHWARTZ, Southeast China - Wind Energy Resource Mapping, National Renewable Energy Laboratory, for U.S. Environmental Protection Agency, May 1998.
23. S. CHEN, Wind Farm Analysis and Integration, Assignment Report from (China's) Electric Power Research Institute to NREL, Presented in Washington, DC, 18 July 1997.
24. China Energy Review 1997, prepared by Resources Conservation and Comprehensive Utilization Department of the State Economic and Trade Commission.
25. William CHANDLER, GUO Yuan, ZHOU Dadi, China's Electric Power Options: An Analysis of Economic and Environmental Costs, Presented to the China Council for International Cooperation On Environment and Development, Pacific Northwest National Laboratory, Report PNWD-2433, June 1998.
26. CHEN Heping, Energy Conservation is an Important Component of Sustainable Development Strategies of China, China Energy, Oct. 1997.
27. Energy Information Administration, International Energy Outlook 1997 (Washington, D.C., April 11, 1997).
28. Ministry of Science and Technology, State Development and Planning Commission, Notice on Further Supporting the Development of Renewable Energy, Reference Number: (1999) #44.
29. S. HUANG, K. ZHENG, The Latest Progress in Exploration and Utilization of Geothermal Resources in China, Proceedings of the World Geothermal Congress, Florence, Italy, 1996.
30. Z. LIO., Energy and Its Utilization in China, Geothermal Resources Council, Vol. 21, September/October 1997.
31. Z. KEYAN, C. JINRONG, Growth of Geothermal District Heating in China, Proceedings of the World Geothermal Congress, Florence, Italy, 1996.
32. P. ZHAO, J. JIN, J. DUO and T. LIANG, Deep Geothermal Resources in the Yangbjing Field, Tibet, Geothermal Resources Council, Vol. 21, September/October 1997.
33. W. FLEMING, Ground-Source Heat Pump Design & Operation Experience in an Asian Country [China], Transactions of the American Society of Heating, Refrigeration and Air Conditioning Industry (ASHRAE), January 1997.
34. A. HOFFMAN, The New World Ahead, Geothermal Resources Council Bulletin, Volume 26, Number 5, May 1997.
35. D. JHIRAD and K. LANGER, Accelerating China's Renewable Energy Program, International Energy Agency Meeting Paper, Beijing, May 1997.

执行总结

本报告由中国科技部（前中国国家科学技术委员会）与美国能源部共同组织编写。进展报告包括了两国能源效率及可再生能源技术发展与利用领域合作协议（以下简称协议）下的所有活动。本报告重点总结了协议前三年的工作情况。该协议通过了 1998 年 11 月 4 至 5 日召开的联合工作小组会议的评审。

中国能源及环境问题

目前中国是世界上能源消费第二大国，排名美国之后（中国 1995 年能源消费约为 35×10^5 英国热量单位，美国能源消费量为 88×10^5 英国热量单位），同时也是世界最大的煤炭生产及消费国。电力生产中火电占垄断地位（中国 1995 年约占 75%，而美国约占 51%）。中国对煤炭的过分依赖已经导致了多种环境污染，包括酸雨、烟雾、有毒废物、水污染及二氧化碳排放等。现在中国碳化物排放约占世界的 13%，仅次于美国位居第二。随着过去二十年中国经济的持续增长，预计到 2015 年这段期间，对能源的需求将以每年 4—5 个百分点的速度增加。据美国能源部能源信息局预言，按照这个增长速度，中国到 2025 年可能超过美国成为世界上最大的能源消费及温室气体排放国。

中国认识到了环境问题的挑战性，以及在保持经济和能源发展的同时，采取有效措施来保护环境和社会利益的必要性。主要措施有：利用能源效率和可再生能源技术，降低对煤炭的依赖，为偏远农村地区和海岛地区约 6000 万无电人口提供电力。1992 年 6 月里约热内卢的世界环境发展大会召开之后，中国制定了“中国 21 世纪议程”。该议程强调利用能源效率、可再生能源、清洁煤技术、燃气联合循环发电及核电技术。1994 年 3 月，中国国务院批准了“中国 21 世纪议程下的可持续能源计划”。

随后在“九五”计划（1996 年至 2000 年）中，中国制定了几个宏伟的政府计划，包括“光明工程”，“农村能源综合建设项目”，“绿色照明工程”和“乘风计划”。此外，1991 年 11 月 1 日中国人大通过了《节能法》。制定这些计划和政策的目的是利用能源效率和可再生能源来降低单位能源消费量（单位国民生产总值消费的能源），为偏远地区提供低成本电力，降低对环境的破坏。

中美能源效率及可再生能源协议

应原国家科委主任和中国国家气候变化委员会主席宋健之邀，1995 年 2 月，美国能源部部长 Hazel O'Leary 带领了一个可持续能源及贸易总统代表团到中国访问。访问期间双方签署了七项新协议，其中包括能源效率及可再生能源协议。

该协议包含了三个可持续发展目标：（1）通过促进中国能源资源多元化，来提高世界能源安全度、降低未来对石油的需求；（2）在能源需求快速增长的同时，利用可再生能源及能源效率缓解对环境的破坏；（3）加强美国工业在中

国能源市场的竞争力。

该协议下的活动也是对美中环境与发展研讨会第二次会议主题的支持。这次环境与发展研讨会于 1999 年 4 月 9 日在华盛顿召开，由中国总理朱榕基与美国副总统戈尔共同主持。研讨会还包含了由美国能源部和中国发展计划委员会共同主持的能源政策工作小组会议，讨论了以下领域各项协议的许多问题：可再生能源、能源效率、石油和天燃气、清洁煤技术、煤矿甲烷气及其它能源技术。

环境与发展研讨会及工作小组第一次会议于 1997 年 3 月在北京召开。在能源和环境领域初步讨论成功的基础上，1997 年 10 月，美国能源部秘书 Federico Pena 和中国国家发展计划委员会主任曾培炎，共同签署了一项能源与环境合作联合声明。该声明旨在加强双边合作，帮助中国满足能源需求，提高当地、地区及全球对环保以及气候变化的重视。声明中还确定了优先发展的三个合作领域：城市空气质量、清洁能源和能源效率以及农村电气化。

该协议促进了中美环境与发展研讨会主旨和能源与环境合作声明目标的实现，通过发展能源效率和可再生能源，促进这些能源的利用，来满足中国农村电气化和环保的要求。协议下的合作包括：技术援助、培训、政策分析、资源和市场评价以及信息交流。该协议含有六个附件，其中四个与可再生能源有关，一个与能源效率有关，一个与电动车和多燃料汽车有关。

协议执行及完成情况：

附件 I：农村能源发展——1995 年 6 月 27 日与农业部签署了本附件，旨在通过户用可再生能源技术的利用，如生物气化、风能、光电及风/光互补系统等技术，为中国农村地区提供能源或电力。合作活动有建设农村电气化试验项目、培训与人员交流以及举办中美农村电气化研讨会。三个项目的成功实施已经为中国农村能源发展奠定了坚实的基础，并且可以推广至中国其它地区。

甘肃户用太阳能系统项目——在美国能源部可再生能源实验室和中国农业部的支持下，美国光电照明基金会与甘肃光电照明基金会于 1998 年完成了 320 套太阳能光伏户用系统的安装工程。此外还在十所学校安装了美国生产的 53W 光伏系统。本项目的直接成果是在甘肃省政府的支持下，由甘肃光电照明基金安装了另外 275 套光伏系统。本项目的成功可使农业部在西北六省区推广户用光伏系统至 10000 户。青海和新疆正在进行市场情况调研，分析影响光伏技术持续发展的社会因素和经济因素。

农村生物质能合作——美国能源部可再生能源实验室与农业部合作进行了生物质能资源评价，对中国生物转换技术的能力进行了描述，并对生物质能系统作了初步的技术经济评价。这些初步的数据和调查报告已用中英文两种语言分三册在中国出版：（1）中国生物质资源可获得性评价（2）中国生物质能转换技术发展与评价（3）生物质能技术商业化发展策略设计，同时附有 CD 光盘。

内蒙古风/光互补户用项目——1997 年，Delaware 大学和美国能源部/可再

生能源实验室共同完成了家庭及村镇规模的电力系统案例分析，其中包括 41 户家庭和三个村镇的技术性能和经济分析。此后美国能源部/可再生能源实验室和内蒙古新能源办公室共同建设了一个试验项目，已安装了 96 套户用风/光（450-500W）系统，到 1999 年和 2000 年还要安装 125 套和 120 套户用系统。美国为该项目提供了美国产的光电板。本项目的另一个成果是东乌旗地方政府完成了一个可行性研究，并计划在以后五年内安装 4000 户互补系统。

附件II：中国风能开发——1996 年 10 月 25 日与电力部（现为国家电力公司）签署了该附件，旨在加速中国并网型及独立运行型风电的大规模、可持续发展。该附件的目标是，在美国能源部、国家可再生能源实验室和美国风能界的支持下，为先进风能技术的技术及经济可行性作以示范，促进其商业化发展，使两国受益。合作内容包括资源评价、公用事业风电厂分析、融资研讨会、风光互补微电网分析、项目开发及培训计划的人员交流。

主要项目有：

风资源评价和测绘——美国能源部/国家可再生能源实验室与美国环保局合作，于 1998 年完成了中国东南部风资源评价和测绘工作。包含的省区有江西省、福建省和广东省东半部。风资源条件较好的地区以及适于建设风电项目的地区在测绘图上都有明显标记。风资源条件最好的地区是沿海地区及离岸海岛，尤其是福建沿海一带，那有许多风资源条件极好的地区在测绘图上都有标注。风资源评价工作仍在继续，采用的是当地电力局数据和美国九个测风仪收集的数字数据。

小青岛村电力项目——美国能源部/国家可再生能源实验室和国家电力公司正在黄河出海口山东省的小青岛建设一个试验项目，采用风/柴/蓄电池互补系统为 120 户居民提供电力。美国能源部将为项目提供 4 台 7KW 的风力机、蓄电池、一台 40KW 逆变器及备件。国家电力公司为项目提供柴油发电机、风机塔架、基础、地面建筑及配电系统。此外国家电力公司还为美国能源部/国家可再生能源实验室收集运行及性能数据。该项目预计可于 2000 年底试运行。

附件III：能源效率——1996 年 10 月 25 日与国家计委（现为国家发展计划委员会）签署，主要有 10 个工作领域：（1）能源政策（2）信息交流和商业发展（3）区域取暖（4）热电联产（5）节能建筑（6）节能电动机系统（7）工业工艺控制（8）节能照明（9）非晶变压器（10）融资。双方从工业、政府机构和能源协会中选出代表成立了 10 个工作小组，为工作开展分析障碍、寻求机遇。1997 年美国能源部和中国国家发展计划委员会共同主持召开了能源效率指导委员会工作会议，对过去的工作进展进行了评价，对以后的工作进行了讨论。主要的活动有：

电动机系统——1998 年 5 月，美国能源部代表团在北京召开了一个电力系统电动机挑战的研讨会，并计划于 1999 年夏季召开水泵系统第二次研讨会。国家发展计划委员会准备将其作为国家项目加以实施。

能源效率政策——中国正在执行 1997 年 11 月 1 日签署的节能法。应中国的邀请，美国专家于 1997 年 12 月召开的研讨会上讨论了美国有关能源效率法律、政策及标准的实施。

节能建筑——已经准备了节能建筑合作的行动方案。

此后，能源效率第二次会议于 1999 年 6 月在北京召开。本报告未来得及将会议结果概括在内。

附件IV：可再生能源商业发展——1996 年 10 月 25 日与国家经贸委签署了本附件，由国家发展计划委员会能源研究所的可再生能源发展中心负责项目的实施。该附件以可再生能源政策的分析与制定、信息交流、商务发展、培训以及项目融资为主。活动包括：

省级可再生能源商务情况调研——可再生能源发展中心与美国国家可再生能源实验室合作完成了两个商业发展调研。第一次调研于 1996 年底进行，描述了六个省区（甘肃、内蒙、青海、山西、新疆、浙江）影响可再生能源发展的因素。1998 年对另外四省（广东、江西、吉林和云南）进行了第二次调研，并讨论了中国政府机构改革后的变化。

中国光伏工业和技术评价——1998 年对当地光伏商务及应用进行了评价，评价报告将于 2000 年出版。该活动包括与当地许多光伏电池及光电板厂家、销售商及集成商的会谈。可再生能源发展中心和美国的专家对中国的光伏技术和工业发展作了回顾。

附件V：电动车及混合动力汽车的发展——1997 年 11 月 18 日与科技部签署了该附件，旨在促进信息交流，加强经济、环境与政策的研究合作以及培训的活动。

信息交流——1997 年和 1998 年进行了两次重大的合作性访问。双方同意将信息交流作为第一阶段合作的优先活动。迄今为止，许多有关电动车基础设施要求的出版物及资料，如建筑规程和安全标准，已送到科技部。1999 年准备通过网站传播电动车及混合动力汽车的更多信息。

附件VI：地热发电及利用——1997 年 11 月 18 日与科技部签署了该附件，合作框架为地热发电技术、地热直接使用及地热泵基础设施的建设。

地热钻探支持——1998 年 9 月美国能源部为云南腾冲地热项目提供了钻探技术支持及地球物理勘测。中国准备在此建设一个 10MW 的地热发电厂示范项目。

地热泵项目——中国已计划在三个示范城市（大庆、上海、广州）的三座商业楼采用地热泵技术，总面积达 340 万平方英尺。美国能源部已经同意在可行性研究和培训方面提供技术支持，作为交换，中国则要为该项目购买美国生产的设备。在中国三个温带地区采用地热泵系统的综合可行性研究将于 1999 年 8 月完成。

结论：

美国和中国是世界上最大的两个能源消费国，开展双边合作对双方都有益。在共同的能源安全、环保及经济目标上可建立合作伙伴关系。将中美合作协议转为合作框架的工作已取得重大进展，在加速中国可再生能源和能源效率技术引进的研究和开发工作上也取得重大进步。协议的六个技术附件已制定出来，并正在实施。除这些协议附件外，两国的政府机构和工业界还进行了大量有价

值的信息交流互访活动。有 30 多家美国公司正在与中国有关机构讨论或制定商务活动。已经开展或规划的试验项目有太阳能、风能和地热能、电动车、能源效率技术。这些项目都属协议下的直接活动或技术支持及接触下的间接活动。已经签署了一个合资企业协议，其它的商业化企业也正在商谈中，这会加速两国的经济合作和贸易发展。协议活动的最终结果可降低温室气体排放，开辟新的、清洁的和可持续的能源，提高能源效率，支持农村电气化，通过商务发展使两国互利。

1.0 背景

1995 年 2 月 25 日，美国能源部与中国国家科学技术委员会，即现在的中国科技部，签署了一项能源效率及可再生能源利用与发展领域的合作协议。此后便确定了与其它政府机构的合作活动，签署了六个协议附件并正在实施。

全球能源需求增加，尤其是中国能源需求增加引起的环保及可持续发展问题，是两国考虑的重要问题，因此签署了双边合作协议。双边科学与技术合作应鼓励清洁能源的使用，支持可持续发展，通过贸易、经济发展和能源安全需求的增加使双方受利。

该协议的成果会使两国都受益。高新技术领域进行的信息交流有太阳能、风能、生物质能、能源效率、交通以及地热技术等。对选定的技术，双方受益的技术交流促成了中国试验项目的建设。这些工作会促进清洁能源利用和可持续发展目标的实现。有 30 多家美国公司与中国同等数量的企业参加了协议活动，这为商务发展和合资企业带来良好的前景。从 1995 年项目开始，两国投入资金约 200 万美元，并已取得环保收益和商务发展成果。

本报告为协议下可再生能源与能源效率领域的工作进展报告。报告中讨论的专题有以下领域内计划开发的活动、正在进行的活动以及已经完成的活动：附件 I 农村能源发展，附件 II 风能发展，附件 III 能源效率，附件 IV 可再生能源商务发展，附件 V 电动车及混合动力汽车发展，附件 VI 地热发电与利用。

1997 年 10 月，在美国总统克林顿和江泽民主席的首次会晤上，美国能源秘书 Federico Pena 与中国国家发展计划委员会副主任曾培炎签定了能源与环境合作计划联合声明。这是对美国副总统戈尔和朱榕基总理主持召开的美中环境与发展大会目标的支持。用先进的有益环境的方式帮助中国满足能源的需求，需要考虑到当地、区域及全球的环境问题，以及气候变化问题。五年计划的目标是加强双边合作，通过加强技术合作提高私人企业对中国能源发展的作用，推进能源政策与投资条件的改革、改善，鼓励私人投资。合作计划要通过确立合作草案和协议来实施，这包括能源效率及可再生能源领域合作协议。计划中明确的优先合作领域有：城市空气质量、清洁能源、能源效率以及农村电气化。

1998 年 6 月底克林顿访华期间，能源与环境问题再次被提上议程。1998 年 7 月 2 日克林顿参观桂林期间，在关于环境问题的讲话中指出这一地区的重要性。克林顿说：“去年十月份中美两国首脑会晤时，江泽民主席和我建立了清洁能源合作计划的开端。这一周我们的工作取得了重要的新的进展。我们要为

中国提供空气质量监测帮助，要加大合作力度，支持中国可再生能源的发展，降低中国对煤碳的依赖性。”

经过与中国政府机构多次的讨论与会晤，美国能源部同意在 1998 财年和 1999 财年继续对协议项目和可再生能源双边合作项目提供支持。附件 6 能源效率及可再生能源协议下的工作有举办培训和研讨会，开展风能、太阳能、生物质能、地热 、电动车、农村电气化及能源效率方面的商务发展活动。该项目的详细活动本报告中有阐述。

1998 年 11 月 4 日至 5 日，协议工作小组第一次会议在华盛顿召开。这次会议由中国科技部的石定寰和美国能源部的 Allan Hoffman 共同主持。在美国能源部能源效率及可再生能源助理秘书 Brian Castelli 的发言致词中，指出这是中美两国政府联合工作小组的首次会议，旨在开发新能源，促进能源利用的可持续发展及环境效益。会议总结了项目进展情况，制订了未来的工作计划。见图 1。中国代表团还参观了加利福尼亚州的几个可再生能源工业项目。

2.0 中国对可再生能源及能源效率技术感兴趣的原因

中国有着丰富的可再生能源，并关注本国的环境问题和能源供应问题。中国的节能活动开始于 80 年代早期，主要是解决全国能源短缺问题。1990 年国家气候变化协调小组成立，主要进行政策研究和国际机构协调工作。随后，中国 21 世纪议程[参考 1]出台，确立了中国 21 世纪可持续发展的战略。在中美合作协议项目的支持下，21 世纪议程计划取得重大进展。

中国 21 世纪议程的第 13 章是关于能源生产与消费的可持续性、开发可再生能源及提高能源效率。议程的部分工作是发展新能源和可再生能源，包括详细估算可利用资源，明确发展目标，以及实现目标所要开展的活动。以下为可再生能源及利用的案例[1,2]：

1993 年，由农作物废弃物、薪柴及其它各种有机废物组成的生物质能占中国能源供应量的 25%，相当于 2.6×10^8 吨标准煤。在农村地区，这些燃料提供了能源消费总量的 44%，农村家庭能源利用的 69%。大量的固体、气体和液体燃料形式的生物质能未被利用，尤其是在中国东部和南部省份的农业地区。

风资源蕴含量估计为 1,600GW，其中约有 10%可以开发。至 1998 年底，中国投入运行的风发电厂总容量达到 223MW。最好的风资源场址在中国北部省份和沿海地区。

地热能蕴含量还未得到全面勘测，现已探明的储量相当于 3×10^9 吨标准煤当量，约有 0.33×10^6 吨标准煤的地热资源正在开发利用。

太阳能资源非常丰富，广泛分布在中国 600 多万平方公里的地区，主要是西部和北部省份以及南方一些沿海地区。许多地方年平均辐射量每平方厘米超过 600 千焦，可以与美国太阳能条件最好的地区相比。

1995 年，随着人们对环境的日益关注，在九五规划的指导下，许多独立的集团和机构开始发展新能源和可再生能源技术。中国科学信息研究所重庆分所收录了这些研究开发成果，并收集了科技部、国家经贸委和国家发展计划委员

会的有关资料。该信息已出版成书，广泛传播于国内外，并为下一个五年计划的工作奠定了基础。

中国 21 世纪议程的重点是提高能源效率和节能。这些工作会大幅度提高能源效率。单位能源消费量，即单位国民生产总值消费的常规商品能源量，从 1980 年起已降低 50%，或每年降低 4.5%。然而，中国的单位能源消费量仍比美国高 3 倍，所以提高能源效率就势在必行了。

中国常规能源的需求自 1980 年以来翻了二翻，能源消费也转向电力和气体燃料。除了最近经济有些低迷，中国经济整体呈发展趋势，与亚太地区国家总体情况和经济快速增长情况很相似。1980 年至 1990 年中国的国民生产总值年平均增长率为 9.5%。1992 年、1993 年中国国民生产总值增长率高达 13%，而南方一些经济特区工业产值年增长率超过了 20%。最近经济的增长速度有所减缓。1998 年中国实际的国民生产总值增长率为 7.8%，与年增长率为 8%的政府目标相符，预计这会持续至 2015 年。中国抑制经济的发展对控制通货膨胀已经起到作用，1997 年中国的通货膨胀率约为 5%。1998 年为-0.9%，1999 年为 2.5%。在可见的未来，控制通货膨胀和提高国民生产总值年增长率仍然会是中国政府的政策目标。

中国经济的增长给中国政府和工业基础设施造成了许多压力和紧张。至今遇到的能源问题有：电力需求的增加与电厂和电网系统建设延滞的矛盾，对煤、天然气或其它能源的需求和采矿、运输及燃料加工手段的矛盾，燃料消费的增长与由此引起的空气和水污染的矛盾，对通过财务稳定和贸易平衡来调节的风险资金和商业融资的空前的需求。目前中国的电力工业处于供过于求的状况，部分是因为亚洲经济危机引起的经济增长缓慢，还因为一些地区电厂建设过剩。可再生能源发展与能源效率对其中某些问题有所影响，下面会有详细阐述。

与经济发展同步的是对电力生产增容的需求，不仅以此满足工业、商业和日益增长的中级消费者的新需求，还要填补电力供需的差额。中国农村仍存在电力长期短缺的现象，全国有 1/3 的地方未被电网覆盖。为了满足对新能源的需求，国家电力公司对新电厂建设的一个战略性计划提供了支持，制定的目标是 1995 年至 2000 年间每年增加发电容量 16GW。该发展速度现已被缩减（1999 年），但以后发电容量肯定要增加。

中国近期规划的发电容量增长多是采用 300MW 至 600MW 范围的火力发电汽轮机，这会大大增加近期电力生产对煤的依赖。煤作为中国的常规商品能源，其比重由 1980 年的 74%增加至 1995 年的 78%，根据国际能源机构提供的数据，占世界比重的 24%。中国因此而成为唯一一个对单一能源依赖很重的国家，在煤的消费量上仅次于美国。中国的电力生产主要依赖于煤（约 75%），也只消耗了燃煤量的 29%。世界银行计划到 2010 年中国产煤量的 40%要用于发电。中国现在的产煤量约为每年 1.2 亿吨[13]。根据国际能源机构的资料，1996 年中国和美国的煤炭消费总量占全世界电力生产用煤的一半。

对煤的依赖程度越高，付出的代价也就越高。1991 年，煤和石油的利用占

中国商品能源利用的 93%，二氧化碳排放量约为 6 亿吨，约占世界二氧化碳总排放量的 10%。中国燃煤产生的二氧化碳量占总排放量的 85%，氮氧化物量占总排放量的 87%。燃煤取热是造成中国城市空气污染的主要原因。并不只是中国大陆考虑环境污染问题。如日本国际贸易工业部，它于 1994 年宣布将对辽宁省沈阳市的几个重建项目提供支持，以减少日本酸雨的形成。

中国已排在世界污染严重的国家之列，由于农村家庭取暖、炊事燃煤，1.73 亿吨薪柴和 2.98 亿吨秸杆的低效燃烧，使得空气污染状况进一步恶化。从 70 年代末期起，在册的汽车每年增加 12－14%，汽车排放的碳氢化合物、碳氧化物及氮氧化物也加剧了城市空气的污染程度。

煤也加剧了基础设施的负担。中国铁路的 50%多是用于煤炭运输，把煤从西部和北部产地运往人口密集的东部和南部地区。电力生产对煤炭的依赖性，迫使中国的战略规划者把重要的基础设施项目纳入到电力生产扩容计划中，进行新的铁路和沿海港口设施的建设,在煤矿附近建造的电场要建设几条主要的东西向和南北向新的输电线网进行电力输送。

中国的石油工业正经历着巨大变化，主要面临着交通领域的石油消费增长的问题。1993 年起中国石油的消费量就已超出国内石油的产量，中国因而成为纯粹的石油进口国。两个国有石油和天然气公司在 1998 年的改组，加强了对垂直合并区域实体的控制。

中国还有农村电气化的需求。1998 年中国还有 6000 万人生活在贫困线上，其中多数为无电人口。为加强扶贫工作，提高人民生活水平，一个最有效的方法就是利用丰富的可再生能源。通常的情况是，能源需求迫切的农村地区，缺乏常规电力供应，却有着丰富的风力资源和太阳能资源。

中国对可再生能源和能源效率技术开发有着浓厚的兴趣，试图借此来满足能源需求，缓解环境问题，就一点也不奇怪了。中国有着丰富的可再生能源，如生物质能、水电、太阳能、风能、地热能及海洋潮汐能。中国已成为世界上最大的可再生能源利用国，主要是生物质能和水电。北京的中央政府通过各部委制定了上述领域可再生能源技术开发的行动计划。

3.0 协议活动

3.1 附件 I －农村能源开发的合作活动

1995 年 6 月 27 日，美国能源部和中国农业部签署了附件 I 农村电气化合作活动，这是能源效率及可再生能源协议下合作与项目开发的第一个活动领域。附件 I 的目标是通过对可再生能源系统的利用，促进中国农村的可持续发展，为农村居民示范这些技术系统的技术及经济可行性，加强中国和美国可再生能源行业的联系。附件允许的技术范围如下，但不局限于此：

村镇规模生物质气化/发电技术

大中型沼气工程技术

太阳能光电和太阳能热水器技术

小风机技术

小水电和微水电系统技术

迄今为止，协议附件Ⅰ支持的项目主要有：（1）甘肃省太阳能户用系统项目；（2）在内蒙古、新疆、青海和甘肃省进行的省级市场情况调研和农村电气化方案分析；（3）内蒙古偏远地区风/光互补户用系统项目；（4）建立中国生物质资源数据库，并附有最终评价与分析。有关这些项目的详细情况参见下面各段。

3.1.1 太阳能光电和风电互补农村电气化系统技术描述

太阳能光电技术，称作“光电”或“PV”，利用无移动部件的固态半导体器件，将太阳能转换为直流电能。风能技术是利用风力机将风中的动能转换为交流或直流电能。这些技术可单独使用，也可与柴油发电机互补使用，也可直接并入电网。

中国的太阳能和风能资源很丰富，在大部分地区都可获得。太阳能是可获得性最广的资源，尤其在北部和西部地区、沿海地区及离岸海岛。如果资源能够得到充分利用，仅太阳能资源就可满足整个中国的电力需求。但是，如此大规模的利用在今天来说是不经济的、不实际的。风资源同样具有地区多样性和丰富性。本报告在附件Ⅱ部分对风能有详细阐述。

附件Ⅰ中的项目主要是小型太阳能和风能系统在照明、通讯、微型企业、冰箱和其它类似的低功率设备中应用。结果是，在电网不能到达的地区，农村居民的生活标准和生活质量有了实质性的改善。

小型独立运行的风电和光电系统在中国北部和西部地区以及有人居住的沿海岛屿地区有很大的市场。世界银行估计青海、西藏、内蒙、新疆、甘肃等 5 个北部和西部的省及自治区，至少有 220 万无电户居住在电网不能到达的地区[11]。中国沿海地区有 300 多个有人居住的岛屿和上千个无人居住的岛屿，近期在这些地区发展电网也是不可行的。而可再生能源是满足某些电力需求的一条途径。

3.1.2 甘肃省太阳能户用系统项目

中美农村电气化合作活动以发展中国西部太阳能户用系统应用为主。一般来说，中国每个家庭的太阳能户用系统的功率为 5 瓦到 150 瓦或更大。中国西北部典型的太阳能户用系统由一块 20Wp 的单晶硅太阳电池组件、一个充电控制器、一个 38AH 密封铅酸蓄电池、两个 8W 荧光灯和一些必要的导线组成。这样的系统零售价格范围为 1800 元至 2400 元人民币（219 至 290 美元），价格越高的系统其质量与可靠性越高。许多牧民和农民能够负担购买这些系统的费用，为他们的孩子晚上读书学习提供照明。通过电视和收音机得到信息交流是很难得的。某些情况下，一些比较富裕的家庭还会购买冰箱和洗衣机。

甘肃的项目由美国华盛顿的光电照明基金会和甘肃省兰州市的甘肃光电照明基金会共同实施，这些组织以前已有工作的基础。该项目的目标是在项目执行期为 600 多户居民和学校提供电力，帮助建立可持续技术利用的基础设施。

能力建设的技术支持有：建设销售和维护网络，综合性培训计划，现货和赊销的试验性财务系统。1998 年秋季，中美合作项目已安装了 320 套系统，在甘肃省政府的支持下，甘肃光电照明基金会安装了另外 275 套系统。此外还安装了十套 53W 的光电学校系统，采用的是 Solarex 的电池组件。

中国农村缺乏信贷经验，很有必要进行持续的部分信贷条款试验，以建立基本的信贷系统。甘肃的项目直接面向甘肃农村的贫穷社区，项目执行期会逐步停止有限的补贴。甘肃省的偏远农区是全中国年收入水平最低的地区。美国光电照明基金会和甘肃光电照明基金会共同在中国建设银行兰州分行开设了一个周转资金帐户，采用用户收条制度促进更多系统的购买，对项目进行调节。

本协议下的示范项目和基础项目是中国其它地区、政府及私人机构活动的模板。国务院扶贫及农村发展办公室是与农业部密切合作的重要部门。该办公室主要负责中国的农村发展项目，每年用于农村基础项目的资金约有 1 亿美元。甘肃的项目为可再生能源技术融入战略计划活动提供一个机制。

在中国大范围利用光电技术的障碍之一是电池组件和平衡系统的部件质量好坏不等。甘肃的项目中引进了部件测试和系统监测的质量控制。美国可再生能源实验室提供了三块在标准测试条件下校准过的电池组件，用作质量控制项目下的二次测试标准。此外，甘肃的项目还开展了大范围的培训活动，对用户和安装人员进行培训，向村镇技术人员和农村能源官员传授市场推广技巧。学习班培训的不仅是光电的基本工作原理，还有光电设计、安装和维护方面的知识。甘肃项目的成果之一是农业部在兰州建立了一个地区测试和培训中心。全国 2300 个县中有 1800 个县农业部设立了农村能源办公室，这些县都可以参与以后的项目建设。

3.1.3 内蒙古风/光互补户用系统试验项目

内蒙古自治区政府在并网型和独立运行型可再生能源技术利用上非常有作为。过去的 10 年中，约有 12 万户家庭利用 100 瓦至 300 瓦的小风机解决了供电问题。此外，偏远地区的农户安装了大约 7000 套小型光电系统（总容量为 120 千峰瓦）。但是，内蒙古农村地区仍有约 30 万户家庭、1100 个村庄和 198 个乡镇没有通电。内蒙古新能源办公室的近期计划是到 2000 年安装 2.5 万套风、光及风/光互补户用系统，远期计划是在内蒙古地区内安装 8 万套户用系统。农村户用系统补贴方式正在逐步停止使用，而以市场为基础的商业化操作方式逐渐得到鼓励。内蒙古的农村人口主要由牧民和农民组成，年收入居全国农村人口最高水平。

附件 I 的合作活动是为了支持呼和浩特市的内蒙古科学技术委员会新能源办公室在内蒙古开发、利用风/光互补户用系统。其它合作单位有内蒙古理工大学、内蒙古大学、北京的中科院、内蒙古商都机械公司和北京计科公司。

可再生能源方案分析

在内蒙古合作活动的第一阶段，Delaware 大学、美国可再生能源实验室、以及内蒙古工作小组对几个县做了农村电气化方案平衡成本分析，根据当地的

可再生能源资源和成本[10]，对可再生能源方案和传统汽油发电机方案进行了比较。1995 年，美国可再生能源实验室、Delaware 大学能源与环境政策中心北京的中科院，开始了内蒙古农村电气化方案的案例研究。该项目由内蒙古计划委员会和新能源办公室合作执行，这两个部门也是负责可再生能源规划的重要机构。其它合作单位有内蒙古大学、内蒙古理工大学和一些地方公司。

案例研究项目对内蒙古中心和北部地区四个县现有的系统进行了平衡成本分析，这四个县分别是四子王、苏尼特右、阿巴嘎和东乌珠穆沁旗。从这四个县收集了太阳能和风能资源数据，从容量在 22 瓦至 600 瓦间的 10 套光电系统、22 套风能系统和 6 套风光互补系统收集了性能/负荷数据。对家庭和大农场常用的功率在 450 瓦至 500 瓦的两种汽油发电机进行了评估比较。

表 1 中列出了案例研究第一阶段的成果：能源平衡成本分析。目前在内蒙古农村地区采用的几种独立运行发电系统中，风力发电是四个县户用系统成本最低的方案。100 瓦、200 瓦和 300 瓦的小风机可在内蒙古当地生产，向户用市场供货。小型风光互补和光电系统的成本要比风力发电系统高，但是所有可再生能源系统的成本都要明显低于汽油发电机的发电成本。

研究结果表明，风/光/电池充电互补户用系统的最优化设计，主要取决于当地的风能和太阳能资源分布以及给定用户的年电力负荷。通常互补系统比风电或光电独立系统更具可靠性和经济性。小型风/光互补系统对偏远农户有吸引力，是因为太阳能和风能资源具有季节互补性。

表 1. **内蒙古农村电气化方案能源平衡成本分析**

系　　统	发电量（度/年）	以 Mfr.引用的电池寿命为依据的平衡成本分析（美元/度）	以实际电池寿命为依据的平衡成本分析（美元/度）
仅用风能	200-640	0.24-0.37	0.50-0.63
仅用光电	120-240	0.67-0.73	0.77-0.83
小型互补系统	400-750	0.31-0.46	0.57-0.72
大型互补系统	560-870	0.32-0.46	0.43-0.57
发电机组（没有提供持续循环使用）	660-730*	0.76-0.80*	0.76-0.80*
发电机组（提供持续循环使用）	480-560	1.09-1.19	1.16-1.27

该表摘自参考文献 10。*按没有蓄电配置的系统进行的估算

内蒙古新能源办公室和内蒙古计划委员会正在制订计划，扩大偏远牧民家庭对风/光互补系统的使用，以实现家庭电气化。美国可再生能源实验室和 Delaware 大学能源及环境政策中心为这两个部门的户用系统优化设计提供了技术支持。按年收入水平来计算，有两类系统得到了人们的亲睐。正在开发的 400 瓦至 500 瓦的互补系统，输出功率在 400 瓦至 500 瓦之间，可为每个家庭提供每天约 1.6 度的电能需求，包括照明、一台彩电和收音机、一台小洗衣机和一个小电冰箱的用电负荷。150 瓦至 200 瓦的更小型系统是为中等收入水平的家庭开发的，每天可提供约 0.6 至 0.7 度的家庭用电负荷，不包括电冰箱或洗衣机。下面讨论的是偏远地区户用互补系统的试验项目。内蒙古政府会将该试验项目的成果应用到其近期安装 2.5 万套、远期安装 8 万套户用系统的项目规划中。项目系统监测部分将通过安装在几户家庭的数据采集系统来收集系统性能数据和太阳能、风能资源数据。

风/光互补户用系统试验项目

目前与内蒙古的合作活动主要是在 1999 年完成 240 套风光互补户用系统的安装。典型的示范系统组成为：(1) 100 瓦的风电与 50-70 瓦的光电互补 (2) 300 瓦的风电与 150-200 瓦的光电互补系统，带蓄电装置。这两个系统每天分别能够提供 0.6 度电和 1.6 度电，可靠性较高。系统提供的电力用于照明、彩电、耗能电子部件及一些可变负荷。450 瓦至 500 瓦的系统还可以带一个冰箱的负荷。食品冷冻贮存是较大系统开发的主要动力，即使在寒冷的气候也一样。内蒙古与戈壁滩南缘相接，夏季就非常热。

对内蒙古进行初步研究、分析得出的结果是，最有吸引力的户用系统方案是风/光互补带蓄电池的系统。该系统比单一的光电或风电系统更可靠，冬季为风资源丰富期，夏季为太阳能资源丰富期。分析表明，农村能源系统采用风能、光电和风/光互补系统比化石燃料发电机成本要低。

3.1.4 太阳能户用系统推广项目

在甘肃和内蒙古项目成功的基础上，在美国能源部和美国国家可再生能源实验室的技术支持和计划帮助下，中国农业部于 1998 年开始了一个新的万户太阳能户用系统项目。该项目将覆盖六个省和自治区：新疆，青海，甘肃，内蒙古，宁夏和陕西。1998 年政府机构重组后，该项目的实施被转交给当地政府机构。机构重组的另一个影响是附件 I 的项目管理权由农业部的环境保护与能源司移交到科学与教育司。

在万户太阳能户用系统项目进行的同时，还对青海和新疆进行了市场情况调研。每个省各选择了五个县采集数据。所选的十个县都是国家农村能源综合发展百县建设项目县。该调研是要在各省进行农村家庭统计取样，用社会经济指标描述家庭特点，如家庭规模、收入水平、旨在评价购买户用系统自发性的电力需求潜力。还要收集有关的技术数据，如农村电气化系统运行性能、发电量、燃料消耗、风能、太阳能以及其它气象数据，进行农村电气化方案分析。通过调研，可以更好地了解目标省份风/光互补系统应用市场的潜力，评价影响

可再生能源技术持续发展的经济因素。最后，把风/光互补系统确定为中国西北部优先发展的技术系统。

中国农业部科学和教育司负责项目的日常工作。中国农业部为项目成立了一个指导小组和一个专家小组。科学和教育司为指导小组领导，小组成员为国务院扶贫办、农业部能源与环境保护中心的代表和项目西北六省农村能源办公室的领导。美方由 Delaware 大学负责，与中国的专家小组一起进行数据的分析与评价。

中国项目指导小组的任务是制定项目目标完成的度量标准，指导项目进行，协调中央和地方政府与研究单位的关系，确保项目的顺利实施，组织必要的工作会议，举办培训活动和研讨会。中国农业工程研究院的能源与环境保护研究所是专家小组领导单位。项目工作小组由国内光电及可再生能源技术专家、经济专家和当地的管理官员组成。

该调研和分析将于 1999 年底结束。这是对内蒙古调研工作的补充，还得到甘肃合作项目中太阳能户用系统及安装家庭调研的补充。

3.1.5 信息交流研讨会

1998 年 9 月 16 日至 18 日，北京召开了一个中国农村电气化小型风力机和太阳能光电技术利用研讨会。研讨会得到了美国能源部、亚太经合组织以及中国农业部的资助，并得到了可再生能源发展中心的帮助。该研讨会的目标是：（1）为中美商业提供中国农村电气化机遇及计划的信息；（2）为中美公司代表提供加强联系的论坛；（3）制定鼓励中美合资企业及其它企业参与中国农村可再生能源电气化活动的政策。有 70 多位中美商业、政府和 NGO 的代表参加了研讨会。美国参会代表有：Solarx，Siemens，美国 ASE，EPV，USSC/ECD，Ascension Technology，SELCO，WINROCK，Bergey 风能公司，大西洋东方公司以及几个农村电气化专家。至少有 15 个中国公司参加了研讨会。

3.1.6 生物质能系统技术描述

生物质能转换技术的利用可以分为直接燃烧、物理转换、生物转换、液化处理和固体垃圾处理技术。这些分类可进一步细分成特定的工艺，如图 4 所示。协议附件 I 中进行的研究主要集中在三个领域：畜禽养殖场的大中型沼气工程技术、生物材料如农业废弃物的热裂解气化技术及城市固体垃圾的处理技术。

生物质能资源可获得的范围很广，主要用于中国的东部和南部人口密集的地区。1996 年约有 2.2 亿吨标准煤的能源消费来自于生物质能资源，包括薪柴、农业废弃物、畜禽粪便及其它[第 1 章,12]，这占中国总能源消费量的 24%。生物质能的利用比早期估计值有所降低，煤和电力的利用有所增加。而农村的生物质提供了全部能源消费的 38%，农田燃料利用的 77%[第 5 章,14]。在中国的许多地区，生物质能足以为整个村庄提供热力和电力供应。

中国农业取得了实质性的发展。随着人口的增长，对高效、高产农业的需求也在增加（如果中国要保持食品净出口国的位置）。目前为止，粮食生产可以

跟得上人口的增长[6]。畜禽养殖也得到了引人注目的发展。表 2 所列为年平均增长示例。农业的发展导致了生物质废弃物的增加及农业商务领域对能源需求的增加。居民生活水平的提高也增加了对许多产品的需求。城市居民亲睐于瘦肉型猪和新鲜的鸡蛋。牛奶不再被认为是奢华的食物。这些发展趋势还会继续，并将导致能源需求的增加，而产生更严重的环境问题[17]。

表 2. 农村畜禽产量增长速度

	年平均增长速度(%)		
年	**1980-84**	**1985-89**	**1990-94**
牛	4.7	3.8	6.5
猪	6.5	5.0	8.0
鸡	20.5	19.8	22.9

资料来源：农业部报告第 2 章，《中国生物质资源可获得性评价》，1998 年[14].

美国能源部、美国国家可再生能源实验室和中国农业部共同评价了生物质能转换技术商业化发展的策略。初步的合作活动是评价市场规模、技术状况以及中国生物质发电项目的潜力。第一阶段获得的信息会被应用到政策制定和投资策略设计中，以加速生物质能技术商业发展和利用的步伐。生物质资源包括农业废弃物、畜禽粪便、蔗渣、薪柴以及城市垃圾。对生物质资源丰富的地区，采用省级和县级地理全图与资源数据相结合的方式可形成初步的地理信息系统数据库。

3.1.7 生物质能资源评价

中国具有丰富的生物质能资源，位居煤、石油和天然气之后第四位。农村农业废弃物蕴含的能源资源（如秸秆）每年约有 3.08 亿吨标煤。薪柴资源约为 1.30 亿吨标煤，与畜禽粪便、城市垃圾一起，每年可用的总生物质能资源超过 6.5 亿吨标煤，这接近中国 1995 年总能源消费量的一半[第 1 章, 14]。

中国农村地区的能源利用约有 38%来自薪柴、秸秆和畜禽粪便[12]，多数生物质能是为 7 亿农村人口提供日常生活的能源消费。随着居民收入的增加，炊事和取热对清洁高效的现代燃料的需求也在增加，这就造成了生物质能现有利用形式逐渐下降、液化石油气和油品的利用会逐渐增加的现象。生物燃料的现代化会降低农村地区对化石燃料的需求，改善生物燃料的环保状况，保持农村地区的收入和就业机会[13 和 14]。

研究和分析中国现有的示范项目所得的资料中包含了大量有关生物能技术的内容。协议草案内研究的专项技术有：(1) 大中型沼气气化技术与热、电以及肥料利用的结合；(2) 城市垃圾处理沼气技术，包括垃圾填埋发电；(3) 炊事、工业/民用集中供气的热气化技术，以及利用农业废弃物供热、发电技术。对所选地区进行的重要技术案例研究作了以下几点说明：(1)所选项目地区的社会、能源、环境和发展战略；(2) 当地政府和居民支持项目的态度和能力；(3) 项目财务和经济分析；(4)项目采用并网型和独立运行型的比较分析。

3.1.8 畜禽粪便沼气项目

畜禽粪便通过厌氧消化池处理后可生成易燃的沼气、肥料以及废水。该处

理过程见图 5。70 年代和 80 年代，中国就在畜禽养殖场建设了沼气工程，主要是为了减缓农村地区能源短缺的问题。现在，由于畜禽集中养殖业的发展和对其进行工业加工（如蒸馏），产生了大量生物耗氧基和化学耗氧基均很高的废水，这些废水最终一般都流入河流、湖泊和入海口，美国和中国都出现了这种严重的环境问题。这种情况会降低水中自然溶解的氧气量，使藻类繁盛，对渔业和饮用水都有着负面的影响。厌氧处理过程能将这类废水中的有机物最多降低 90%。

中国已建设了 460 座大型厌氧处理系统，每年能生产 2000 万立方米的沼气，可为 56，000 户家庭提供 866 千瓦的电力。发展垃圾处理和获得运行经验可能是美国感兴趣的问题。因此，共同研究的一个领域就是确定沼气生产设备的商业生存能力。现代生产过程见图 5 所述。畜禽粪便是主要的原料，主要的产出物是沼气、蔬菜肥料、鱼食、草肥及饮用水。

上海星火农场有一个沼气示范项目。该农场占地 22 km^2，有员工 6,600 人。每年产出的牛粪可生产 75 万立方米沼气，足以提供 3，200 户家庭和 14 个餐馆的炊事和热水需求。这类项目在美国和全世界都应用很广。

3.1.9 农作物秸秆生物气化项目

本附件的一个重要合作研究领域是秸秆与煤共同燃烧（图 6）。农业残渣的过剩和野外燃烧处理能力的低下引起了严重的环境问题。对于燃煤发电应用较广而粮食生产也达大型工业化的省份，如黑龙江、吉林和辽宁，农业部建议调研采用秸秆与煤共同燃烧方式。希望通过中国农业部和美国可再生能源实验室间的合作研究促使电力局也参与示范项目的建设。从美国类似项目的技术交流中获得的经验正用于中国项目的经济与技术问题评价。

另一个领域是通过热化学气化过程将生物质转为气体燃料。其基本原理是把生物质原料充分加热，使有机碳水化合物与高分子物质链断开，分解后即可产生气态碳水化合物和低分子物，如一氧化碳和碳氢化合物。这种转化方式能把生物质原料变为更便于利用的形式，该产物也比直接燃烧固体生物质具有更高的能源转换效率。表 3 可看出各种生物质燃料和煤的气化性能。此外，毫无疑问的是不论从固体燃料还是气态燃料的形式来讲，煤都是高能量、有吸引力的燃料。

表 3. 各种燃料的气化性能

燃料类型	燃料性能				气化密度	气体产量	气体热量值
[1]	湿度 (%)	含灰量 (%)	大小 (mm)	热量 (MJ/m^3)	(kg/m^2 h)	(m^3/kg)	(kJ/m^3)
干木	25	1.0	80-100	13,600	200-250	2.2	4,273
废木	23	1.0	锯屑	13,600	260	2.3	4,360
秸秆	10	3.5	碾碎	14,700	180-220	2.3	4,690
牛粪堆	16	6.0	50*50	11,700	200-230	2.2	3,908
树叶	10	5.0	自然尺寸	13,800	200-230	2.0	3,694

煤（洗去宾夕法尼亚式沥青）[2]	6.5	6.5		24,300		2.0 [3]	12,300 [3]

数据来源：[1]生物质能转换技术，西北大学出版社（中国西安），1993 年
[2] 机械工程师手册，库兹编辑，Wiley interscience, 1986.
[3] Perry 的化学工程师手册，McGraw Hill, 1984.

有三种主要的气化技术：蒸馏、快速高温分解及气化。前两种技术适用于木质或木片的分解。最后一种适于秸秆（如玉米和棉花）的气化。由于秸秆来源分布较广，以及对清洁、便利型农村能源的需求增长较快，秸秆的主要研究就集中于气化技术[18]。

山东科学院开发了一种以农作物秸杆为主的生物质气化和集中供气系统技术。在这个技术中，农作物秸秆被转化为低热量、易燃烧的气体，送入下风设计、床架固定的气化设备，固体与焦油从气体中分离出来，最终就可通过集中供气系统将气体送入一个村庄的各家各户作炊事燃料。请见图 7。经过 10 多年的研究，目前在东坝、张三、腾寨、郇家四个村庄成功运行了四个示范系统。每个村用系统包括以农作物秸秆为主要原料的气化设备、集中供气系统主要设备、通气管道设备及用户、户用燃气炉等。自从示范村庄的第一个示范项目运行后，已经在山东安装、运行了 14 套气化设备。其它地区也建设了这种气化系统的示范项目，如北京，可供 100－200 户家庭使用。

3.1.10 城市垃圾填埋沼气项目

垃圾填埋与自然堆放是不同的。自然堆放指对垃圾不做任何覆盖或科学处理。1980 年以前中国许多城市采取自然堆放的方式。这种技术的缺点是显而易见的。由于垃圾暴露于空气之中，气味难闻，苍蝇、蚊子和老鼠滋生会毁灭垃圾堆放点附近的生态环境，并对公众健康造成危险。同时，渗滤液、重金属和微生物从垃圾中分解出的有害污染物等会渗入地下水，污染水源。

垃圾填埋处理是一种成熟的技术，在防止产生二次污染物影响环境的同时，还可产生易燃气体。垃圾填埋沼气可通过管道收集，用于发电或化学生产。目前全球已建设了 4，817 座垃圾填埋场，每年可生产 5.1 亿多立方米的沼气，相当于 240 万吨原油。

垃圾填埋只是城市垃圾处理方法之一，焚烧是另一种处理方法。每种处理方法适用于不同的情况。垃圾填埋在许多国家都得到广泛应用，因为这种技术不仅易于操作、成本低廉，还适用于各种垃圾的处理及能源的回收。

附件 I 的研究目标之一是帮助中国引进垃圾填埋技术，解决垃圾处理技术问题和二次污染物的问题。主要研究集中于减少土地占用面积、提高效率及减少渗滤液的产生：

增加填埋场的深度，以节省土地、加速垃圾分解并产生沼气；

采用新材料和技术来加强填埋场防渗，并安装渗滤液处理系统防止水资

源受污染；

管道布量和安装以及渗滤液去除；

H_2S 控制；

解决垃圾渗滤液，建设沼气收集管网以提高沼气收集效率；

垃圾压实以阻止空气进入并防止发生氧化反应。

总而言之，随着垃圾填埋技术的提高和运行经验的丰富，填埋技术日趋成熟，附件所列信息传播活动主要有包括以下方面：

合作研究、技术支持及专家交流；

技术出版物及会议。.

中科院成都研究所在中国垃圾填埋技术开发方面居领先水平。其主要业绩有：1985－1986 年完成通过垃圾厌氧渗透进行沼气生产的研究；1987－1990 年完成城市有机垃圾系统化处理研究并通过 160 立方米中试；最近正在建设“无害垃圾填埋场”项目，已经完成的八个垃圾填埋场正在运行中。

垃圾填埋沼气发电正起着越来越重要的作用。燃烧设备为内燃机或汽轮机。Otto 循环内燃机及柴油机最为常用。在垃圾填埋场常配备气化设备，为内燃机提供混合气体。蒸汽轮机和汽轮机也用于某些垃圾填埋场。汽轮机的优点是单位重量输出功率大，其值约为 70－140 千瓦/吨，远高于 27 千瓦/吨的内燃机和 10 千瓦/吨的汽轮机。但内燃机成本低，在中国应用较广，而美国垃圾填埋场应用较多的却是汽轮机。中国有些小型内燃机是便携式的，可以从一个垃圾填埋场移至另一填埋场。

中国正在进行的填埋技术研究和开发主要集中于内燃机的应用，致力于将中国生产的汽油机和柴油机稍加改造变为沼气发电机的开发工作。尽管中国某些垃圾填埋场沼气发电设施已运行成功，但填埋技术整体规模还是很小。迄今为止的研究得出结论，填埋场发电项目所用的发电机类型取决于沼气的产量。内燃机适用于容量为 1,000 至 3,000 千瓦的项目，如果所需容量超过 3，000 千瓦，高效率汽轮机是较好的选择。

3.1.11 村镇规模生物质气化发电项目

正在进行的双边合作项目的一个重要领域就是村镇规模生物质能发电。正进行详细评价的一个系统，由热气化单元构成，可直接将低热值燃气送进各户供炊事用。这种清洁、冷态的可直接输送的沼气也可用于高效发电机发电。目前正在评估的是利用功率为 25 千瓦的斯特林发电机。在美国可再生能源实验室的技术支持下，对浙江、山东和四川三个省做了三个详细的案例研究。山东已经完成了一个秸秆气化提供村级炊事用燃料项目的技术经济分析，并开始了一个由 10 个村庄和另外 24 个计划内村庄集资的示范项目。

3.1.12 报告 已经出版的三个有关中国资源评价双边合作成果的中英文双语报告，有：

"中国生物质资源可获得性评价"[14]
"中国生物质能转换技术发展与评价"[12]
"中国生物质能技术商业化策略设计"[15]

同时还制作了 CD 光盘，包含双方合作努力完成的整套国家生物质数据库，题为："生物质能转换技术商业化与市场开发策略评价"。这些信息资料可从美国可再生能源实验室和农业部获得。

3.2 附件 II　风能开发

1996 年 10 月，美国能源部与中国电力部（现改为中国国家电力公司）签定了附件 II。附件 II 的目标是促进中国并网型及独立户用型风能利用系统的持续、大范围应用。为了两国的利益，有必要进行信息交流、风能利用技术与经济可行性的培训及示范，以加强其商业化发展。

这些目标要通过一系列的合作活动来实现。附件 II 所列活动分三类：(1) 分析及引导各类风电利用示范项目；(2) 信息交流；(3) 合作性研究及交互访问。这些活动是为了帮助中国实现 2000 年底风能装机容量达 100 万千瓦、2010 年底风能装机容量达 300 万千瓦[20]的目标。美国能源部帮助中国实现这些目标，也希望能在两国风能业创造新的商机。

美国能源部通过美国可再生能源实验室向美中两国可再生能源领域的机构提供相互间的培训和技术信息交流。通过这项计划，美国的研究机构和公司了解了中国的电力系统。中国访问者通过使用美国制造的风机、实验室设备及商务软件获得了第一手的资料。

迄今为止在风能方面已进行了四次交流活动。给访问的科学家及工程师都定了专门的研究课题，并被派往国家风能中心工作两至三个月。专门的培训有：(1)为国家电力公司水电规划设计总院的两名工程师提供风资源评价及数据收集方法、风能项目规划技术的培训；(2）为国家电力公司电力科学研究院的一名工程师提供中国东北电网大型并网风电场的经济分析培训；(3）为中科院电工研究所的一名工程师提供风机互补系统在西藏等偏远地区的应用研究。为了加强与美国风能业的联系，中国的访问者参加了美国风能协会年会，还参加了由美国风能业、美国能源部及国际发展组织美国分部资助的为期一周的风能利用及培训座谈会。额外的人员交流计划在 1999 至 2000 年进行。

3.2.1　技术及应用描述

风能在中国可再生能源技术中最具前途，不仅能为国家电网提供可观的电力，还能为电网不能到达的偏远地区提供电力。中国风能资源蕴藏量估计为 1.6 亿至 2.53 亿千瓦[1－21]。而中国 1995 年的总发电装机容量仅为 2.17 亿千瓦（包括火电、核电及水电厂）。 中国气象科学院进行了风能数据汇集，包括不考虑经济与社会条件限制的风能技术可利用量。当然，实际的限制是风能不能独立满足整个国家的电力需求。风的间歇性及对电力传输的限制性使得风能的大规模利用不切实际，而中国许多地区利用并网型风电的潜力却很大。最好的

风址是在东南沿海和北部内陆各省，有内蒙古、新疆、黑龙江、甘肃、吉林、河北、辽宁、山东、江西、江苏、广东、浙江、福建及海南。其它各省也有个别地区风资源很好。

风能应用分析及开发

中国国家电力公司和世界银行都认识到中国风能资源的丰富。风能系统利用主要有三大类（见条块图）。第一类是风机安装在大型风电场里，一般总装机容量为 2 万至 10 万千瓦，风机所发电力送往当地电网。这是风电利用潜力最大的领域，预计内蒙古 2000 年底会有 10 万千瓦的风电并网。

第二类是风机安装在城镇及乡村以解决农村电气化问题，降低电网不能覆盖地区对成本昂贵、污染严重的柴油发电机的使用。这些独立运行型风机的利用，包括在遥远的海岛、独立的社区及自用电的企业成群安装 10 至 100 千瓦的风机。

第三类是风电用于独立用户的照明、通讯（电机及收音机）、健康及生活舒适（冰箱、洗衣机及加热器）。这些应用可与太阳能/光伏和小型汽油发电机结合起来，上面 3.1 节有详细阐述。

中国风电场建设的进展

1998 年底中国风机总装机容量为 2.23 亿千瓦。中国可再生能源领域发展速度最快的就是风电。从 1995 年北京举行第一届国际风能会议起，风电场装机增加了十倍。现有 12 个省及自治区的电力公司从事风电开发，并在中国的两个风资源丰富区建设了 19 个风电场。迄今为止，新疆达坂城风电场的装机已达 6.4 万千瓦，是中国最大的风电场。广东南澳风电场装机容量达 4.2 万千瓦，是亚洲最大的岛屿风电场。

建设风电场和吸引资金的许多渠道

中国风电工业最初是利用丹麦、美国、德国和荷兰的建设资金发展起来的。1994 年至 1997 年，中国风电场外商投资额高于 5700 万美元，多为结合性赠款和贷款。最近，风电场建设已被列入中央政府计划，并有项目计划使用世界银行、全球环境基金及亚洲开发银行的商务融资。

风电产业化的技术与经济进展

中国已经制定鼓励风电发展的规定与规章。现在，偏远地区的许多居民、农民及牧民可以独立购买、安装及运行小风机。风电场所有者可以按风机生产厂家提供的技术文件独立建设、安装及使用风机。中国的一些厂家也具备了生产 0.1 千瓦至 300 千瓦风机的经验。大型风机，如 600 千瓦风机，也可在国内组装。以后还会成立许多生产风机的合资厂。风能杂志的专家说，1997 年是中国的风电年。

3.2.2 中国东南地区风能资源的评价

风能资源评价及绘图是规划风能项目的第一步，也是协议草案风能附件下合作的初步领域。这件工作得到美国能源部、环保局及美国风能协会能源技术

推动计划的支持。中方参与的有中国电力公司水电规划总院和中国气象局。

风能测量计划- 风能评价工作的第一步是建立风资源测量计划，收集详细气象数据，对准备建设的大型风电场项目进行发电能力评价。国家电力公司在 12 个地方建立了风资源测量站，一个靠近上海，两个在江西庐山的鄱阳湖地区，其余在福建、广东的沿海地区。美国生产的测风仪含有数字式数据收集系统，可在两个高度测量风能。中国的技术员与工程师在风机设备安装、运行、维护和结果分析、解释方法上都接受了培训。至今为止，这 12 个测量系统已经收集了几千小时的风资源记录，可为项目产量和经济估算提供准确可靠的数据。

风能评价工作的第二步是进行地区性风资源分析及绘图。这是在几个主要省进行大面积风资源评价，寻找测风计划所需最佳风址的一个成果。中国东南两个地区进行了初步风资源评价及绘图。第一个地区是从广东东南部至福建北部的沿海地区，第二个地区是以江西北部鄱阳湖为中心的地区，包括安徽、湖北两省从安庆附近至南昌附近的部分地区。

在地理信息系统的基础上，采用美国可再生能源实验室开发的大气流量模型绘制了三个地区的风资源图。建模过程采用了数字化地形数据。风资源及其它气象数据与通过几个渠道收集来的一个非常大的数据库相结合。这些数据库包括：该地区所选 85 个气象站采集的信息，从美国国家气象数据中心获得的世界气象组织中国东南部观测站的地表气象观测资料，海船测报的海洋数据，通过卫星微波成像所测波高、无线电探空测风仪与试验气球所测上层空气数据推算出的近海岸风速。

风资源测绘图上显示这两个研究区域许多地方具有较好甚至极好的风资源潜能。高产风区多分布在沿海地区，特别是福建离岸的岛屿。见图 8 [22]。 年平均风速高于 5.5m/s 即可视为风电可利用区。图上许多地方风速很高，但有些地方属山区，地形陡峭，可能很难开发。研究的总体结论是，福建及广东沿海地区，包括离岸岛屿和近岸 10 公里的内陆地区，具有的风资源潜能为 4738 万千瓦。

风资源测绘也有助于确定某一风址风机的最佳定位。该研究的一部分集中于广东南澳岛。如图 9 所示，该岛风资源条件极好，已建立了几个风电场项目，包括美国 Zond 能源系统公司供货的 10 台 550 千瓦风机项目。

3.2.3 并网型风电场分析（东北地区研究）

开始合作的一个领域是分析大型风电场与现有电网并网的经验与技术问题。增加其它能源的成本，降低风机成本，极好的风资源条件，适于大型风电场并网的电网系统，都会增加风能的吸引力。该题目是中国电力科学研究院访问科学家于 1997 年完成的研究课题，他在美国可再生能源实验室工作了三个月。最近的商务计算模型已用于中国东北地区风电并网评价。所研究的东北电网位于黑龙江省 、吉林省、辽宁省以及与内蒙古相接的地区。见图 10。

该研究的重点是探讨与东北电网并网的大型风电容量，以确定其经济成本

与效益。结果显示，即使在非常低的穿透度下，经济性也较好。在美国能源部支持下，比较公用事业有风电场和没有风电场两种情况下运行成本时，采用了环境国防基金开发的电力财务模型。部分研究结果说明风电场容量增加几百万千瓦，当地发电量可增加 1.5%，氮化物排放量减少 2.3%，硫化物排放量减少 2.1%，二氧化碳减少 2.5%。风能的成本为$0.042/kWh (0.34 RMB/kWh)，可降低的边缘成本为 10.5% [23]。中国电力科学研究院获得了在中国使用电力财务模型的许可，且正在进行这方面的工作。此外，中国电力科学研究院计划在供电质量、电网闪变稳定性及风电较高穿透度的控制方面进行研究。

3.2.4 高海拔地区风/光互补系统比较研究

附件 II 人员交流计划中还进行了高海拔区独立运行的各种风/光互补系统的经济比较研究。在西藏的一个村子进行了三种配置选择的研究：风/柴，风/光/蓄电池及 PV/蓄电池。那斯村位于东经 91°30′，北纬 31°50′，距西藏首府拉萨以北 130 英里，在安多县那曲地区。该地区大多数人为无电人口。那曲地区平均海拔约为 4800 米(15,745 ft.)。年平均风速为 4－6 米/秒，年平均日照小时数为 2900 小时，平均温度为－3℃(28F)。那斯村有 57 户人家和一所学校。预计日负荷为：平均每个家庭 5 小时 60W 的电视和 20W 的照明。采用 NWTC 开发的两系统互补计算模型，选择研究成果显示最经济的系统是风/柴互补系统，其次是风/光/蓄电池互补系统。尽管该地区高海拔造成的低空气密度对风能会有影响，但风机相对较低的成本仍使其成为最经济的利用形式。该研究结果发布在 1998 年 19 卷第 3 期 Acta Energiae Solaris Sinica (季刊)，文章名为“西藏 4 千瓦风/光互补发电系统的优化设计”。

3.2.5 村镇规模风/柴互补系统发电试验项目

为给中型独立运行的风能系统作以示范，将会在山东省距鲁山市 4 海里的小青岛建设美国 Bergey 风机的试验项目。国家电力公司之所以选择该场址为典型的岛屿电力系统应用地，是因为其风资源条件好，交通方便，并得到当地政府，包括鲁山市政府、市电力局以及岛屿委员会的大力支持。

小青岛有 123 户人家，346 名居民，目前仅能获得间歇电力供应，在众多的岛屿中具有代表性。岛上的基本工业为渔业和旅游业。发电设备为已使用 20 年的 13 千瓦柴油发电机，通过当地电网配电，电力成本为 3.0 RMB/kWh ($0.42/kWh)。电力主要用于街道照明和居民负荷，包括：照明 (50W)，电视 (80 W)，冰箱 (80 户共 120 W)，洗衣机(50 户共 120 W)，以及电炊具(20 户共 800 W)。晚上电力一般可用 3－4 小时。

计划 1999 年进行风/柴实验项目。现在的计划是在一个小风电场安装 4 套 10 千瓦的风机，与 30 千瓦的柴油发电机、转换器和电池组并接使用。风机及其它电子设备由美国厂家提供（三台风机由美国能源部提供，一台由私人厂家提供）。中方需提供风机塔架、基础和电器设备，并负责设备运行、维护及数据收集。

3.2.6 风电场商务发展培训班

1999 年 3 月 15 日－19 日，普林斯顿经济研究院在中国杭州举办了一个风

电商务发展与政策分析培训班。培训班由浙江省电力局主持，得到中国国家电力公司与美国能源部的资助。参加这次培训的有来自电力系统、省级及中央政府、当地风电场公司及设备制造厂家的 70 名主管人员、规划者、工程师及经济师。授课内容包括世界风能商务趋向及政府运作金融激励、项目贷款及股本融资、现金流量规划与管理、风能及其它可再生能源技术的成本与经济，以及加速中国风电场发展的政策选择。会上介绍了中国 10 万千瓦风电场融资的案例分析。案例分析中列出了七种变化因素造成的影响：风速、项目规模、推广经验和知识曲线、附带条件性援助及中国税务法律、中国银行的特别融资条款。来自 Mees Pierson 商业银行的代表在会上介绍了银行对项目及设备融资的作用及规范。该银行在上海有办事处。之所以选择这家银行作介绍是因为他们在美国已经融资了几个大的风电项目。

3.3 附件 III　能源效率

提高能源效率是中国能源发展战略的一个重要组成部分。中国在提高能源效率方面已取得巨大成就，经济保持高速发展而能源消费却保持较低水平就是最好的证明。1980 年至 1996 年，国民生产总值平均每年增加 10.1%，而年平均能源消费却只增加 5.35% [24] 。

能源效率的一个衡量标准是单位能源消费量，或单位国民生产总值消费能源值。在过去的二十年中，中国能源消费有所增加，但国民生产总值的增长却更快。1970 年末，中国单位能源消费量以每年 4.5%的速率递减。如果单位能源消费量没有减弱，今天的能源消费会增加两倍[25]（见图 11)。

过去提高能源效率仅仅是为了保持能源供需平衡。而现在提高能源效率已被认为是增强竞争力、减轻环境污染及实现可持续发展的一条途径。虽然最近中国及亚洲国家的经济发展有些减慢，但从长远的观点来看，在可见的未来中国经济会以较高的速度发展，能源需求也会以较慢 较低的速率增长。与大多数工业化国家相比，中国能源效率较低，提高能源效率的潜力还很大。因此，提高能源效率会继续成为优先发展领域[26]。

3.3.1　技术及应用描述

按单位国民生产总值所用能源计算，中国在全世界属能源密集型经济，中国工业界的能源消费占中国总能源消费的三分之二多。中国的能源消费集中于化工、重金属、水泥、纸浆及造纸，一般是能源密集型工业。在这些工业领域，能源密集还伴有其它因素造成的能源低效利用，如未掌握节能技术，小厂不能达到经济规模，以及厂内节能运行维护有问题等。此外，中国工业对煤直接利用的依赖程度较高（70％）。

中国决心提高能源效率，中国 21 世纪议程以及九五规划就是很好的证明，这为中美合作创造了机遇：

工业领域：促进余热、废气、废蒸汽的回收利用，扩大热电联产的利用，工业用窑炉的改进，更好的监控系统，绝缘改进及热、气系统改造。还有安装节能设备的机遇，如锅炉、电动机、发动机系统以及相关的

电力设备。

建设领域：由于中国的建设繁荣，在新建和翻新工程、楼体包装、加热系统、通风及空调系统、控制系统以及照明系统的改进工程中，都有着稳定的机遇。

设备购买的增加：也创造了向用户宣传购买节能产品的机遇，提供了能源效率规范及标准合作上的需求。

3.3.2 合作领域

在指定小组领导的带领下开展了美中能源效率活动。小组由来自企业、政府机构、能源协会、美国能源部国家实验室及其它有兴趣单位的代表组成。中国曾组织过类似的小组。成立了专门的指导委员会来协调美中能源效率及可再生能源技术开发与利用合作协议下的能源效率活动。指导委员会主席由中国国家发展计划委员会的李洪勋先生和美国能源部的 Denise Swink 女士共同担任。委员会由中国国家发展计划委员会、美国能源部代表和中美小组领导组成。1997 年 5 月 5 日至 7 日，美中能源效率指导委员会第一次会议在北京召开。1996 年 10 月签署的附件 III 包含了有关能源政策、信息交流和商务接触、区域供热、热电联产、节能建筑、节能电动系统、工业工艺控制、照明、非晶变压器以及融资等方面的能源效率活动。至 1998 年 10 月，所开展的活动和工作分以下十个领域：

3.3.2.1 **能源政策**- 开展该活动的目的是加快能源效率技术推广政策上的合作。美中能源政策合作获得大量资料证明后，工作重点转向：（1）评价美国能源政策对中国的适用性；（2）帮助中国制定标准。

1997 年 7 月，美国能源部政策办公室向中国国家计委发出了有关法律、规定和政策执行方面的信息单。1997 年 11 月 1 日，全国人民代表大会通过了中华人民共和国节能法，于 1998 年 1 月 1 日起生效。随后，一个美国代表团来中国参加了有关能源效率政策方面的研讨会。1997 年 12 月 11 日至 12 日于北京召开的这个研讨会，汇集了美国联邦及各州执行能源效率法和政策情况的讨论。美国代表团成员包括自然资源国防委员会、节能联盟、美国能源效率经济委员会、加利福尼亚能源委员会、Lawrence Berkeley 国家实验室和美国能源部的代表。

还合作制定了重要产品的指标和标准，如冰箱、空调、镇流器和荧光灯。中国技术质量监督局正在发布节能标准。冰箱的标准于 1997 年建立，荧光灯的标准于 1998 年开始执行，空调的标准 1999 年到期。1996 年 6 月，为帮助建立冰箱节能标准，Lawrence Berkeley 国家实验室为三个中国访问者培训了能源效率分析工具。

3.3.2.2 **信息交流和商务接触**- 信息交流是中国能源效率信息收集和传播的重点。传播的信息主要是有关技术、市场条件及其它感兴趣的内容。西北太平洋国家实验室(www.pnl.gov/china)和北京节能研究所(www.gcinfo.com/BECon)在

全球网站上发布的中国信息有：技术资料，简报，与其它网站的链拉，中国能源、环境和经济的统计。每月一期的中国能源效率信息简报也公布在网站上。针对美国公司提出的有关中国电力的问题，西北太平洋国家实验室、北京节能研究所和中国能源研究所，于 1998 年 6 月出版了一份报告，全面反映了中国电力出路的选择。可在西北太平洋国家实验室的网站上读到该报告。

3.3.2.3节能电动机系统- 美国和中国都致力于推动中国高效电动机、电动机速控及其它提高电动机系统效率技术和经验的开发、商业化及利用率。在美国能源部资助下，美国能源效率经济委员会与北京节能所和上海电器设备所合作进行了中国电动机市场调研。调研公布的结果可从美国能源效率经济委员会获得。此外，美国小组还向中国提供了电动机、计划和产品的资料，以帮助美国电动机生产商把握在中国建立合资企业的机遇。

目前要在美国能源部电动机计划成功实现的基础上，致力于制定并执行中国电动机挑战计划。工作的一部分是交流有关电动机系统的资料，包括风扇、压缩机和泵系统。1997 年 12 月与中国节能投资公司讨论后，达成了于 1998 年 5 月在北京举行电动机挑战研讨会的意向。美国代表团由来自美国能源效率经济委员会、Lawrence Berkeley 国家实验室和美国工业界的代表组成。研讨会过后，美国草拟了一个中国电动机系统节能计划修订行动方案，其中含有背景材料、计划目标、短期、中期和长期计划，中国节能投资公司审阅了该方案。项目的目标是先在一个省建立主要的国家计划，为评价国家计划提供一个实验室。目前正在寻找该计划的资助。

3.3.2.4区域供热- 对中国五个地区的供热系统进行更新，是区域供热计划的一部分。已在烟台的两个公寓楼安装了加热表，其中一个还安装了热调节阀。示范项目从 1997 年 11 月开始，至 1998 年春天结束。对能源利用和节约及居民舒适度都进行了评估。与中国建设部会谈结束后不久就会公布评估报告。建设部考虑要将项目扩展到整个烟台地区的供热系统。还考虑召开一个研讨会，将示范结果传播给中国更多的大众。

3.3.2.5 热电联产- 热电联产活动的目标是与美国投资者和合作者一起推广中国的热电联产项目。作为该活动的一部分，1996 年 6 月，中国节能投资公司、国际能源资源和 Lawrence Berkeley 国家实验室共同在华盛顿举办了美中热电联产专家研讨会。 中国主要的热电联产开发者和政策制定者与有兴趣的美国私人合作者会聚在一起，交流对美国投资开放的热电联产项目。.

中国节能投资公司准备了有关中国热电联产的情况、热电联产项目批准过程及相关政策的资料。由于经济情况发生了重大变化，这些资料还需更新。为了降低中国联产项目的经营成本，美国小组草拟了电力购买、蒸汽销售、合资企业协议的文件模板。1998 年 7 月，美国小组向中国节能投资公司提供了中英文两个版本文件，由中国节能投资公司向全国及地方的有关单位分发。中国节能投资公司统一意见后，准备将该文件作为模板用于全国的热电联产项目。

3.3.2.6 节能建筑- 1998 年 1 月完成了行动方案。该方案提出美国和中国有必

要彼此加深对建筑业的理解，并评价美国节能建筑技术对中国的适用性。中国和美国计划举办两个研讨会。第一个研讨会准备在美国举办，第二个准备在中国举办。为了帮助实现初步计划，美国能源部建筑技术办公室资助两个中国研究员在 Lawrence Berkeley 国家实验室进行访问性工作。屠风翔教授（中国建筑节能协会）和刘剑平（中国节能投资公司）这两名研究员，将准备背景资料并协助组织研讨会。

3.3.2.7节能照明　中国绿色照明计划是“九五”期间一个主要的节能计划。作为这个计划的一部分，中国正致力于提高节能灯具的数量和质量，推广节能产品。该节能照明将在以下几个方面帮助绿色照明计划：培训、产品认证和商标、照明标准、公众信息及促进建立合资企业。

1997 年夏季，中国绿色照明小组，在联合国开发计划署项目支持下，访问了美国的生产厂和 Lawrence Berkeley 国家实验室。美国专家在北京绿色照明年会上做了演讲。此外，1997 年秋季，中国国家技术监督局的代表团参观了 Lawrence Berkeley 国家实验室，学习制定产品测试、认证及商标计划。1998 年 5 月，中国决定继续申请全球环境基金赠款，将中国绿色照明计划推广至全国。计划的主要组成有：继续产品认证和商标计划，节能照明产品改进，促进购买正品，制定并执行教育、激励和财政计划，制定设计和产品标准，做市场趋向调查。

3.3.2.8非晶变压器- 非晶金属是变压器铁芯的一种新材料，它能在升高及降低电压等级时减少设备的能源损耗。非晶金属变压器的应用是为了提高中国非晶金属铁芯和变压器的设计及制造水平，推广非晶金属配变电的应用， 从而降低能源损耗，提高能源效率水平。降低成本很重要。美国小组领导，同测公司曾与中国变压器厂家一起工作，把非晶金属变压器的溢价从 1995 年的 70%降到 1997 年的 25%，目标是 1999 年以后还要低于 20%。

1998 年 1 月，国家发展计划委员会公布了一封信函，函中阐述了在中国大范围推广非晶金属变压器产品的步骤。1998 年 5 月，同测公司和通用电器公司与上海志新公司签署了一份协议，允许其使用通用电器的非晶金属技术。新厂正在建设，预计 1999 年可开工。到那时，上海志新公司就可从通用电器进口加工完的变压器，从同测公司设在浦东的工厂购买非晶铁芯。新厂建设完成后，变压器溢价低于 20%的目标就可望实现了。

3.3.2.9工业工艺控制- 该活动的目的是进行工艺改进，至少要在中国九个不同的工业公司进行。该计划要求为三个工艺以内的至少三个工厂的设备进行工艺改进方案鉴定。随后，参与者要召开研讨会，进行现场参观，为安装先进的工艺控制技术进行合同谈判。目前的工作是获得执行方案所需的评估。

3.3.2.10　融资　开展融资活动的目的是寻找限制中国能源效率融资的因素，为能源效率融资寻找出路。小组主要进行三方面的工作：(1) 增强公司透明度－明确有权执行合同和项目的单位；(2)安全性－提供还款及融资担保；(3)项目初期支持－获得当地支持进行可行性研究并提供项目初期的其它费用。

1997 年 5 月，美国西北太平洋国家实验室接待了中国节能投资公司的一名代表，他在融资和未来合作发展潜力方面作了研究。美国小组仍会继续开发能源效率项目并为其融资。中国节能投资公司为美国公司编制了一本中国项目批准程序指南，待其修改完成后即可公布。

3.4 附件 IV　可再生能源商业发展

1996 年 10 月 25 日，美国能源部和国家经贸委签署了可再生能源商业发展协议附件 IV。中国可再生能源发展中心执行或协调该附件下的主要活动，以促进中美工业合作伙伴间的合作。开展该活动的目的是推广节能和能源效率商业发展，提高可再生能源在中国的利用率。至今为止，已经开展了能源政策分析、技术信息交流、商务和专业培训等活动。这些活动的重点是建立联系、选定项目并为可能的项目融资提供途径。

在能源和能源效率领域美中两国有许多商务机遇。1997 年，中国从美国进口了约 1.4 亿美元与能源有关的产品和服务[5]。目前还未对可再生能源和能源效率商务做过调查，但已经知道的是约有 20 家美国公司签署了合同，正在寻求机遇，在协议参与单位的帮助下已建立了几家合资公司。参与协议活动的美国公司有：Allied Signal, Arco, Arthur D. Little, Atlantic Orient, AWT, Bechtel, Bergey 风电公司，能源资源国际公司，Enron, GE, GM, Honeywell, Jacwill 服务公司，普林斯顿经济研究院，Solarex, Therma Source, Water Furnace, Unocal, 和 Zond 能源系统公司。此外，协议还促进了中美两国电力公司、大学、投资银行、非政府组织和工贸团体间的信息交流。

协议签署后中美两国间的商务活动得到增加。还为中美两国工业和政府的领导组织了几个商贸代表互访团。1998 年，Bergey 风电公司和湘潭电机公司在俄克拉荷马州签署了可再生能源领域第一个美中工业合资公司协议，在中国生产并销售 10 千瓦的风机。他们计划每年在中国生产 300 套产品以满足快速增长的需求，还可能为中国国家发展计划委员会解决农村电气化问题的光明工程提供风机。

中国已经采取了很多措施来鼓励可再生能源的商务发展。如对某些产品减免进口税和税金。1998 年 1 月 1 日起，免除 300 千瓦以上风机的进口税，小风机进口税为 12%。对高技术项目，如风能、太阳能和其它可再生能源技术，也有特别税率。对在高新技术开发区注册的企业或合资企业，有两年免收所得税（一般为 33%），三年减半征收所得税的规定。此外，中国科技部和国家发展计划委员会还发布了支持可再生能源发展的特别通知，鼓励国内银行给可再生能源建设项目优先贷款，提供 2%的贷款贴息及其它财政激励[28]。

3.4.1 省级商务发展情况调研

在美国能源部的支持下，可再生能源发展中心组织了两个商务发展情况调研组。主要收集可再生能源潜能、当地政府和企业关心的可再生能源技术、控制项目执行的程序和规定及其它可能对可再生能源发展起正面或负面影响的因

素。第一个调研于 1996 年底开始，进行了六个省的市场潜力调研：甘肃、内蒙古、青海、山东、新疆和浙江。第二个调研于 1998 年 6 月开始，进行了另外四个省的调研：广东、江西、吉林和云南 ，并对因中央和地方政府机构改革引起的变化作了说明。最终报告提供的市场信息对想进入中国可再生能源市场的美国公司会很有用的。

这些调研都提到了几个欧洲国家提供的混合贷款或附带条件的援助性项目的影响。这些报告发现美国风机公司在小项目上与欧洲公司竞争还要有一段时间。然而，多数附带条件的援助性项目都小于 3000 万美元，美国进出口银行给美国公司提供贷款的期限和条件可以与附带条件的援助性项目竞争。这种竞争性援助已经用于三个 1 万千瓦的风电场项目建设，但对企业来讲，它比欧洲采用的方式时间要长，手续更复杂。以后附带条件的援助性项目所起的作用会越来越小，一旦进行大型的可再生能源项目，他们会更愿意采用商业银行或国际银行融资方式，并且是采用公开竞争的方式。

3.4.2 对世界银行和其它多边项目的支持

美国能源部通过可再生能源实验室对联合国开发计划署、世界银行及其它多边机构在中国的活动给予了支持。此外，美国能源部还与美国可再生能源和能源效率界一起将可再生能源和能源效率作为可行的投资领域加以推广。

美国能源部向联合国开发计划署和世界银行提供了技术支持、经济分析以及风资源评价，以支持其在中国开始的可再生发展项目。在其中一项支持性研究中，世界银行作出这样的总结，“不再需要提供特定政策和机构限制，研究表明可致力于三项技术的大规模市场开发：并网型风电场、光伏（特别是太阳能户用系统）以及蔗渣热电联产[11]”。美国能源部和可再生能源实验室的技术支持为世界银行正在中国进行的贷款额高达 4 亿美元的可再生能源项目提供了帮助。此外，联合国开发计划署也正在进行 2600 万美元的可再生能源项目。

3.4.3 商务发展机制和激励

美国进出口银行给中国提供了 1 亿美元的可再生能源信贷基金。最初融资可用的安全贷款额为 5000 万美元。后来增加为 1 亿美元，可用于购买美国可再生能源项目和能源效率技术开发范围内所有的商品和服务。符合贷款条件的项目有：风能、太阳能、垃圾燃烧联产、地热技术、蔗渣燃烧厂、节能建筑改造、电动机节能设计升级以及其它清洁能源技术。申请者可申请直接贷款或贷款担保。还款期限、负债程度、利润回报应尽可能好，并在经济合作与发展组织的指导下申请贷款。

3.4.4 项目开发与融资培训

1998 年 6 月至 9 月，可再生能源发展中心的四名人员参加了美国可再生能源实验室资助的一系列培训项目。设计这些培训活动是想通过参与项目的机构支持中国能力建设，提高项目选址分析能力，对项目评估和开发采用实用性经济分析方法，把美国在可再生能源政策制定方面的经验带回中国以起到促进和加速的作用。培训活动由以下几部分组成：(1) 地理信息系统软件支持与分析的培训，与科罗拉多州 Boulder 的环境系统研究所建立合作关系；(2) 生命周

期分析；(3)美国可再生能源政策发展及其对美国可再生能源技术商业化发展的支持。

1999 年 4 月，中国国家电力公司组织、美国能源部举办了一个“怎样加速中国风电发展”的研讨会，本报告 3.2.6 有详细阐述。美国公司、普林斯顿经济研究院举办了主题为“风能商务发展与政策研究”，为期三天的研讨会。会上70％的人员由中国国家电力公司北京总部从各省电力局、计划委员会和风机私人公司中选定的。培训的目的是根据美国安装 200 多万千瓦风机的经验，为参加者提供开发大型风电场的关键商务知识。讨论的话题包括：可再生能源财政激励、风电场经济分析、项目融资和签约以及影响成本的因素。要通过这些来加速中国可再生能源技术，特别是风能的发展与利用。

美国能源部支持的另一个培训项目是资助中国国家电力公司、电力研究机构、省电力局和当地计划委员会的五名重要人物参加 1996 年和 1997 年每年一度的风能利用培训座谈会。在美国能源部和美国其它政府机构的支持下，美国风能协会组织了为期两周的培训项目。集中座谈会涵盖了并网及独立运行情况下风能利用发展、融资及运营方面的所有问题。

3.4.5 光伏工业调研及机遇报告

1998 年 9 月至 10 月，Sherring 能源公司组织了一个为期 40 天以美国人为主的代表团，对中国 7 个省的 11 个城市进行了考察。代表团想通过考察获得有关中国光伏工业、应用和市场的第一手资料，对美国公司在中国发展的商务机遇做以评价。可再生能源发展中心对该代表团提供了支持。美国可再生能源实验室将于 1999 年出版题为“中国光伏商务与应用情况评价” 的报告。

该报告提供了中国光伏领域从事组件及系统平衡部件生产、系统集成以及应用开发的 20 多家光伏公司的概况及联系信息，评价了中国光伏工业和市场开发的现状，提出了光伏市场持续发展的障碍，并为中国以后的商务发展提出建议。该报告还提供了中国采用光伏技术进行的其它国内项目和国际项目信息。

该调研得出结论，中国的太阳能光伏生产业发展迅速，但却面临巨大的挑战。详细结论如下：(1) 每年有上万套的太阳能户用系统现金市场；(2)需要改进集中生产电池的设备，制定统一的产品性能指标和电池及其它系统部件（包括充电控制器）的质量控制标准；(3)追求低成本导致了产品质量不高；(4)需要在省一级建立示范项目以取得经验和完善技术。

3.4.6 光伏背景报告

可再生能源发展中心准备了一份题为“中国太阳能光伏系统商业化”的报告，计划于 1999 年以中英文两种语言出版。报告中详细阐述了中国光伏市场及应用情况，包括中国光伏发展的历史回顾。该报告和研究对 3.4.5 节提到的光伏工业调研是一个补充，同时也提供了有资格参与世行农村电气化项目的公司的详细资料。

3．5 附件 V　电动车及多燃料汽车的发展

汽车工业是中国快速发展的支柱产业之一。由于其对国民经济的重要作用，

汽车工业得到了中央政府的大力支持，政府支持使得生产能力与产品质量均得到了提高。预计 2000 年汽车的生产能力可望达到 1200 万辆，2010 年将增加三倍。但另一方面，汽车数量的增加却会带来环境与能源问题。机动车是中国各大主要城市的主要污染源，而且机动车辆污染仍呈上升趋势。例如，北京 1989 年机动车辆所排放的一氧化碳占一氧化碳总排放量的 39%，碳氢化合物占 75%，氮氧化物占 46%[19]。机动车辆的增加及交通状况的进一步恶化，促使政府集中精力研究和开发电动及多燃料汽车技术。

1997 年 11 月 18 日签订了协议附件 V《电动车及多燃料汽车开发》，1997 年 12 月在美国华盛顿召开了首次会议，1998 年 8 月初美国附件 V 工作小组访问北京，与科技部代表展开了进一步的讨论，并参观了中国电动车研究机构及汽车生产厂。在此期间，双方同意在以下四个主要领域加强信息交流：

技术转让：基础的、无专利权技术的协调，重点是建立标准及测试方法，强调在中国先进的机动车技术计划中形成高水平的杰出技术与自治能力。美方经验证明对于一个完善的计划，这些内容是至关重要的。

实施：基本实施政策与实际问题的协调。应用美方经验，以加快计划的实施，适应中国快速发展的机动车市场。各类研讨会将促进信息的交流，继而推动中国先进机动车辆的开发、生产和应用。

环境保护：基本因素的协调，即以环境可接受的方式，发展先进技术的机动车辆。包括：确保中国政府及企业采取必要措施，实行安全运输、车载式应用、先进技术的零部件与子系统的回收或利用。

创造小企业发展机会：发展机会的协调，即在先进机动车辆所需关键技术上为小企业创造机会，与中国汽车制造企业共同发展。通过多种多样的机构，类似美国已建立的机构，如小企业联合会，为小企业创造商机。

美方附件 V 小组已认识到中方计划的庞大及许多技术与实际问题。双方原则同意加快进度，鼓励更多企业参与。工作小组认为促进信息交流与私人企业参与是很有必要的。另外，开设工厂与建立示范项目都将是协议中所要使用的重要方式。总的来说，中美计划面临着同样的问题。

技术转让方面，将在中国与美国研究机构间寻找研究人员或合作项目内部交流的机会。内部交流重点为先进的电池及燃料电池技术。1999 年，计划制作网页，传播电动车及多燃料汽车方面的信息。此后，下一步重点将是寻求私人企业间的联系，以便与中国政府及各商业实体一起，执行合适的计划。美国能源部将和中国相关机构将共同需求国际银行与开发组织资金及其它项目的支持。

3.5.1 技术描述及背景

中国正在开拓其汽车工业在运输领域的发展，包括石油工业，如汽油、柴油等传统运输燃料。但是随着化石燃料消耗的不断增长，特别是对进口燃料需求的不断增长，人们开始越来越关注其对经济及环境的影响。尽管已投入很大努力，提高现有油田的油回收技术，开发中国南海及中国西部丰富的石油资源，特别偏远的塔可拉玛干沙漠中的塔里木盆地，但油进口量仍在持续增长。在塔里木盆地，新管道已铺设到另一个规模较小、但地理位置较近的吐鲁番-哈密或

吐哈盆地。

在市区，汽车引起的大气污染正在成为一个日益严重的问题。在一些主要大城市，空气中碳氢化合物、一氧化碳及臭氧的含量已超出中国的标准，而这些主要是汽车，特别是机动车辆造成的。尽管北京机动车辆的数量仅为洛杉矶与东京的十分之一，但其尾气排放量却与其它两个城市相同[1，19]。

中国汽车工业被认为是支柱型产业，部分受中央计划经济控制。目前私人货车、客车的销售、服务与使用正在持续增长。汽车生产厂正将重点从生产重型卡车及公共汽车转为生产轻型客车，特别是私营客车。1990 年重型卡车及公共汽车的产量占总产量的 65%，而目前，轻型客车的生产增长最快，与前 5 年相比，1990 至 1995 年产量翻了一倍，见表 4。

表 4 已登记民用车辆增长迅速

资料来源：世界银行及中国统计年鉴 1996

车辆类型/所有人（10^3）	1985	1990	1995	1985-1999 年平均增长率
客运车辆	795	1622	4179	18%
专业公司	83	108	131	5%
货运车辆				
私人	19	241	786	45%
卡车	2232	3685	5854	10%
专业公司	194	198	142	-3%
货运车辆				
私人	265	573	1226	17%
其它	616	411	1227	7%
总计	3643	5718	11260	13%

国际商务交往拓展了汽车工业的发展，在中国、美国、欧洲及日本的合资企业中，新的生产组装厂正在投入运营。通用汽车公司是受邀在中国建立汽车组装厂的企业之一（生产小型别克车）。Chrysler 通过与北京吉普车厂合资，目前正在生产约 100，000 辆汽车，其中 80%以上部件均在中国国内生产。

电动车及多燃料汽车（即可选择燃料）的研究在中国方兴未艾。1996 年，电动车项目列为国家科技攻关项目。时下，研究计划的一部分集中在锂电池、镍金属氢化物电池及燃料电池上。电动车测试及示范区已在汕头-南澳建成，17 辆电动车已投入测试 2 年。电动车样车的总体设计也在进行之中，关键部件的设计已取得重要成果。根据计划，电动概念的汽车将在 2000 年生产完毕并投入试用。

目前正在进行多燃料汽车技术的经济评价，以确保研究成果切实可行。作为低污染或无污染车辆，预计电动车将成为 21 世纪重要的运输工具。中国计划引进世界先进技术，以创造性方式发展新型汽车技术。

3.5.2 工作计划

为了制定工作计划，中美之间已举行多次技术讨论会。1998 年，美国能源部/工业代表团访问了清华大学及中国科学院的电动车研究机构，同时还参观了北京吉普车厂，会晤了各部门多数电动车部门，探讨了可合作领域，主要为：

电池管理及充电状态控制器 – 清华大学 Delphi 汽车研究所提供广泛的、多学科的现代汽车工业所需的，在管理技能方面的技术培训。清华大学汽车工程及计算机科学与技术系已生产了大量改装电动车，包括电动自行车、4 座电动轿车及 16 座电动面包车，使用的均为直流电机，直流控制器及溢流（管状阳极板）铅酸蓄电池。同时，清华大学还与美国通用汽车公司一起正在开展电池管理系统及充电状态指示研究。

交流电机控制系统 – 中国科学院电工所正在开发交流电机控制系统，用于 50kW 范围内中国产电动车。研究小组正在探索不同类型的电机：感应电机，永磁电机，同步电机及开关磁阻电机。在这一方面有合资的机会，生产电源开关或微控制器芯片。

标准 – 中国正在四个领域制定标准：车辆总系统，控制器及电机，电池，电池充电。这与美国汽车工程师协会所采用的方式类似，无论是美国的还是中国的企业都可以从双方共同的、可兼容的标准中受益。

蓄电池及燃料电池技术 – 中国正在致力于开发先进的电化学技术，同样美国也正在从事这方面的工作，包括电动车所用的镍金属氢化物及锂电池。目前正在探讨在两个国家实验室间进行科技人员互派及交流的可能性。

技术转让 – 技术转让内容为 1997 年 11 月附件Ⅴ第一次会议所达成协议的内容，涉及领域为：

1. 目前美国联邦政府计划的组织 – 美国能源部将提供总体信息，用于构造中国电动车计划。
2. 快速充电 – 美国能源部将以美国 Aero Vironment 及 Norvick 在这一领域所完成工作为基础，提供总体技术资料。
3. 交流电机控制器 – 美国能源部将提供关于美国交流电机控制器状况的总体报告，鼓励美国小企业在这一领域可能达成的合作，包括 Unique Mobility 及 AC Propulsion。

实施 – 美方小组将在制定实施计划及管理步骤方面提供技术支持，将审查前期已完成工作，包括 1995 年关于鼓励购买和使用电动车的研究，1997 年电气企业参与程度研究。同时还将审查美国的其它计划，包括清洁城市及电动车备选城市计划。中国正在考虑开展类似的研究及制定类似的实施计划。

环境保护 – 两国都对环境问题十分关注，以避免由于使用新型汽车技术而引起的新的、或意料之外的环境问题。双方合作可确保全面考虑所有重要的环境问题。合作的一个领域是环境评价，美国可再生能源实验室先进备用电池工作小组已做过先进电池的环境评价，基础工作委员会对现行工作也作过环境评

价。合作将引导中国加入合适的国际工作小组，制定与先进电池相关的测试及其它方面的国际标准。

小企业参与一 在制定中国电动车计划中，美国小企业对可能参与的领域很感兴趣。

3. 6 附件 VI　地热能发电与利用

在中国地热资源日渐重要，且具有极大的潜力。地热资源不但可用于发电，而且还可直接用于加热或制冷。美国已在这些领域，开发出了先进的技术，同时，企业界也对此表现出了浓厚的兴趣。在这种情况下，1997 年 11 月 8 日中国科学技术委员会（现科技部）与美国能源部签订了地热发电与利用联合行动协议之附件六。本协议的目的是加速中国地热资源的应用，包括地热发电与地热能的直接使用。 协议中所包含的合作领域有：地热应用与地热资源的规划与分析及科技人员交流与互访。

在地热资源直接利用方面，中国居全球领先地位，中国地热资源丰富且具有悠久的应用历史，1990 年热功率为 2，000MW_{th}，热能生产超过 5，000GWh[5]。从明朝开始，温泉便被用于环流供暖及疾病治疗。目前，中国共有 1620 个地方正在直接使用地热能[29]，所产生的能量相当于燃烧 500 万吨标准煤。正在使用地热能的地方包括：112 个地方用于农业生产，51 个地方为工业应用，65 个地方为温泉旅游，35 个地方为地震观测站。

中国地热资源分布广泛，已有资料证明全国范围内分布着丰富的地热资源，包括 2500 个温泉及 270 个地热田，初步探明地热能可采储量相当于 4.6X10^{11} 吨标准煤[2]。温泉大多分布在福建、云南、四川及西藏自治区。高温的地热资源集中在喜马拉雅地带，喜马拉雅地带为地中海地热带的延伸，经过西藏南部，四川西部及云南，向南穿过泰国。而分布在中国的地热带非常巨大，长度超过 2800km，宽度为 200-400km。西藏羊八井地热田的某一地方（图 17）已被发现为地热资源最好的地区之一，在 2007m 深度处，地热流体温度为 329.8℃[30]。这极好的说明了该地区具有优良的中、高温地热资源。

3.6.1 技术及应用描述

地热能系统利用地球内部传导热损耗，形成蒸汽、热水或借助其它传热工作流体直接使用，如建造环流供暖/供冷，或驱动涡轮机发电。这两种不同的应用方式以下均有所介绍。

地热发电

几千年来，人类都在使用温泉及汽泉洗澡、做饭、采暖。本世纪由于技术进步，使得人类有可能定位和开挖到热水储集层，将气体或热水输送到地表，直接利用热量进行环流供暖，农业及工业生产或驱动汽轮机将热能转化为电能，而这些在经济上也是可行的。储集层温度决定了能量转换过程，同时对经济特性也有很大影响。只有高于 200℃（392℉），及介于 100℃到 200℃（212℉-392℉）的地热资源才适于发电。

地热发电总装机容量已达到29MW，同时计划进一步扩容。在一些地热电厂，埋藏较深，温度较高的资源用来生成蒸汽进行发电。目前最大的电厂为羊八井地热发电厂，距离西藏自治区首府拉萨市西北 94 公里。该电厂最高容量为 25MW，自 1979 年起，每年生产电力约 100TWh，为拉萨电网提供约 50%电力[29，32]。云南省也在建设一个发电厂，公开招标将很快推进位于腾冲附近热海地热田的开发。

地热泵

地热泵为一种经济可行、节约能源、对环境无危害的建筑物供热及制冷方式。利用地球相对稳定的土壤温度在一年中进行供热及制冷。地热泵与地球的热交换是通过一套埋藏在地下的塑料管路系统，称为地热交换器，见图 18。冬天，管路内液体吸收地球热量，并通过系统传送至建筑物内部。夏天，建筑物内部热量被吸收，通过系统埋藏在凉爽的地下。建筑物内部的风扇用于传送热或冷空气，工作原理类似空调。地热泵可节约运营维护成本，供热及制冷所需能量的 70%均来自地下。

目前大庆（100，000 平方米）、上海（100，000 平方米）、广州（120，000 平方米），总计 320，000 平方米（或 340 万平方英尺），正在建设三个地热泵示范项目，用于建筑物供热及制冷。地热泵是一种经济、节能的选择，很值得在中国推广。

地热的直接利用

中国同时还在扩大地热能的直接利用，已建成两个示范点，一个在河北省雄县，用于建筑物空间供暖和热水供应。另一个在湖南省汝城，用于作物种植和水产养殖。

3.6.2 地热泵应用的可行性研究

地热泵技术为未来最有潜力的应用技术。但对其在不同条件下及不同地区的所面临的技术、经济问题，却未得到很好的掌握。另外，中国有不同的气象带，因此要求使用不同类型的地热泵系统。在北方寒冷气候带，冬季平均气温在-10℃至-30℃间（14° F 至-22° F），地热泵可用于补充或替换燃煤供热锅炉。在中部温暖气候带，主要为长江流域，冬天气温在-5℃至 10℃（23° F 至 50° F），夏天则非常炎热，温度在 30℃至 40℃间（86° F 至 106° F）。在这样的地区，应使用双功能地热泵空调系统。在南方亚热带气候带，包括广东、福建、海南、广西及香港，夏天炎热，每年 7 个月的时间需要空调，而冬天温暖，无需供暖。

在以上三个不同气候带内，使用地热泵的技术及经济可行性正在研究之中。美方将为中国三个地热泵示范项目提供技术支持。

示范项目将研究地热泵的不同功能及如何适应中国不同的市场需求，计划在三个气候带各建立一个示范点，分别为：

中国北方气候带，大庆市商务综合建筑。

中国中部气候带，上海的商务项目将示范地热泵技术特性，包括一将

用作上海闵行经济技术开发区中心的多层商务办公楼，完全为地热泵系统空调。

中国南方气候带广州市附件大型商住综合楼。

中国计划购买美国现有的地热泵，美国能源部计划通过协助企业提供技术培训和支持，支持这项大规模投资，包括支持项目可行性研究，技术培训，教育，及合作项目的评估与管理。

此外，研究还将说明应用地热泵技术的技术可行性，重点是浅部地下水资源的输送，深层地热资源的输送及地表水资源的输送。该研究还将说明应用地热泵提高中国环境质量的效益和风险。

3.6.3 腾冲地热发电示范项目

针对提供技术支持的要求，美国能源部派遣了两名美国地热专家前往中国腾冲地热项目，研究钻探设备、安全及地质问题。钻探专家汇报，腾冲钻井队在油田及气田钻探方面有着丰富的经验，可达到钻探深度要求。但他们缺少地热钻探方面的经验。在一些情况下，这类钻探必须配备合适的设备、材料及工具，而这些在当地或者没有，或者未正确使用。他们向中国钻探队特别建议，应提高操作安全性。同时认为专用的钻探设备是必要的，而且也是经济的，可大大节省钻探成本。地热勘探专家报告，目前正在钻探的地点距离资源所在地过远，这样液体温度及流量均会受到影响，建议更换到附近另一个地点。该地点有很多大型岩石断面，预计水温很高，经济上将更可行。为了帮助中国完成腾冲前 10MW 地热示范项目，美方专家建议：（1）地质及地球物理支持；（2）钻探工程支持；（3）现场培训；（4）钻探后分析；（5）未来钻探计划的制定。美方在地热研究及开发上的长期历史及专家，对于实施中国的计划是非常有益的，将会创造许多双方均会有所收益的商业机会。

3.6.4 地质科学研究

美国能源部通过 Lawrence Berkeley 实验室正在资助一个地热装置的科学研究，该装置将安装在腾冲，以生产地热能资源。通过研究井下岩石样品中的惰性气体同位素（氩、氦、氖、氪、氡、氙），有可能确定热源是变质的，还是来自流入地表附件的火山岩浆的。这些资料对于大陆运动研究是很重要的，可预测地热能生产潜力。

4．0 商业项目开发及融资

4．1 能源及环境

1997 年 10 月，签定了能源及环境初始合作联合声明，目的是加强双边合作，以一种保护当地、地区及全球环境的方式，来协助满足中国能源需求。初始阶段将集中在能源与环境科学，技术进步及中美贸易上。联合声明中确定的优先合作领域有郊区空气质量、清洁能源、能源效率及农村电气化。联合声明的一个重要目标是通过鼓励政策，促进私营企业投资，通过政策、规定的及投资改革的不断执行，寻求鼓励私营企业更多投入中国能源发展的方式。联合声明支持的能源及环境初步计划包括：开展研究，共享数据，加大可再生能源的活动应用，其它清洁能源技术，能源效率，促进以上技术领域内贸易及投资。

初步计划同时还期望，通过使用清洁能源来解决中国不断增长的能源需求及农村电气化的实现目标。计划合作领域包括：

市区空气质量标准- 与政府合作处理与空气污染相关的能源问题，包括市区空气质量监测，实行排放标准，居住环境问题（建筑材料、家庭采暖及做饭），减少铅排放，加强企业对天然气基础设施建设的参与，煤气化，生产和使用高效燃料的汽车，排放监测设备及提高汽车燃料质量。

农村电气化及能源资源 – 加强企业与政府参与，帮助将清洁能源引入农村，使用并网及独立风能、太阳能、水电与天然气等可再生能源。

清洁能源及能源效率 – 加强企业与政府参与，帮助开发和使用高效能源的电机、工业废热发电、工业处理、照明、小区供热、变电所及建筑物，发展清洁能源技术替代化石燃料系统，发展大型风电及太阳能系统。

与全球气候、环境、能源安全相关的问题影响着人们的健康、安全和生活质量。中美能源效率及可再生能源备忘录提供了一个合作框架，按照一种更有利于可持续发展的方式向人们提供电力。这个问题的迫切性也许还有待讨论，但提高效率，将化石燃料燃烧转换为氢气或其它燃料及尽可能使用可再生能源的长期需要确实不容置疑的[34]。备忘录中所囊括的各项活动无疑会加速这种转变过程[35]。

4．2 EXIM银行清洁能源计划

EXIM 在中国私营电力项目融资方面具有丰富经验。另外，EXIM 银行已授权向中国政府提供 1 亿美元出口信贷资助涉及可再生能源及能源效率技术的项目购买美国设备及服务。该信贷机构是在对洁净能源深入了解的基础上建立起来的，于 1999 年 3 月 29 号由国家发展计划委员会、美国能源部、EXIM 银行和中国发展银行共同签署成立。符合条件的项目有：风能、太阳能、地热能技术；节能建筑；以及低 NO_x SO_x燃炉。

4.3 会议及研讨会

有许多由中国科技部，美国能源部，以及其它美国和中国政府机构联合赞助召开的会议。召开这些会议旨在鼓励私人企业参与中国可再生能源的利用，提高能源效率，促进可持续发展。

1998 年 9 月 22-23 号，中国能源融资会议在北京由美国商业部、能源部和中国国家发展计划委员会联合召开。本次会议将参与能源项目开发与融资的众多美国公司和中国政府的有关部门代表，确切地说是中国地方和省区电力机构，汇集到了一起。美国商业团体对此反应也较强烈。本次会议美国私营团体和中国政府方面均超额参加，参会人数超过 275 人，其中包括 175 名公司代表。本次会议被认为是促进商业发展的一次有用且成功的会议。

5.0 结论

自美国和中国就能源效率及可再生能源领域开始进行合作的 4 年期间，美

国能源部/中国科技部取得了实质性的发展。中国在开发工具和搭构商业框架上取得了成功，证实了可再生能源和能源效率的技术经济可行性。这些合作活动对成功地展示太阳能光伏技术、风能技术、生物能发电、地热能以及电动汽车技术作出了贡献。此外还出版了许多技术刊物。这些活动也为美国的工业带来了可能的长期受益，包括促进建立新的商业伙伴关系、拓宽美国产品市场、中国试验项目购买美国设备等。一些美国和中国制造业公司建立的合资企业已经在这些方面间接获益。所有这些活动培养了一支各方面训练有素的美中联合队伍，能以双方获益的方式胜任或从事复杂的双边能源工作。

6.0 参考书目

1. 中国 21 世纪议程，《中国 21 世纪污染、环境及发展白皮书》第 13 章：可持续能源的生产与消耗。
2. 中国科学技术信息所，《中国新能源及可再生能源技术与生产》，NRSE 中国信息网络办公室，重庆分办，1995 年。
3. 世界银行，《新世纪的中国环境，2020 年中国碧水蓝天》，1997 年 9 月。
4. 美国能源部，能源信息办公室，《中国－国家分析简要》，www.eia.doe.gov/emeu/cabs/china.html，1999 年 6 月 13 日。
5. 美国能源部，能源信息办公室，《国家能源简介：中国》，1997 年 10 月。
6. 世界银行，《中国 2020 － 新世纪的发展挑战》，1997 年 9 月。
7. John BYRNE, SHEN Bo, William WALLACE，“农村发展中可持续能源的经济性：中国农村可再生能源研究”，《能源政策》，26 期 45-54，1998。
8. William WALLACE, TSUO Simon, “中国农村电气化中的光电系统”，《光电专家会议电气与电子工程研究所论文集》，1997 年 10 月 3 日加利福尼亚 Anaheim.
9. Jack STONE, TSUO Simon,ULLAL H.S., et al.，“印度及中国光电系统电气化：NREL 在国际合作中的经验”，《光电研究应用规划》，6，341-356（1998）。
10. John BYRNE,et al.，《中国内蒙古小型独立光电，风电及光电-风电复合系统成本分析》，Delaware 大学能源与环境政策中心，Newark,Delaware，1996 年 3 月。最新报告将出版。
11. Anil CABRAAL,et al，《中国可再生能源发电》，9 月，世界银行 15592-CHA 号报告，1996。
12. DAI Lin, LI Jingming, Ralph OVEREND，《中国生物能源转化技术：发展及评价》，中国环境科学出版社，ISBN 7-80135-552-0/X-1335，1998 年北京。
13. L.SUN, Y. WANG, Y.AN，“中国生物能源转化技术及其发展环境”，《世界能源委员会亚太地区论坛论文集》，pp.165-177，中国北京，1997。
14. DAI Lin, LI Jingming, Ralph OVEREND，《中国生物质资源可获得性评价》，中国环境科学出版社，ISBN7-80135-545-8/X-1331，北京，1998。
15. ZHANG Zhengming, DENG Keyun, Ralph OVEREND，《中国生物质能技术商业化策略设计》，中国环境科学出版社，ISBN 7-80135-756-6/X-1400，北京，1999。
16. Y.ZHAO, L.WU，“中国沼气能源技术及发展前景”，《世界能源委员会亚太地区论坛论文集》，pp.178-188，北京，1997。

17. Z.SU, Z. HUANG, J.LI，“中国大中型畜禽养殖场粪便资源可利用性研究”，《1998 中国生物量和生物能》，美国可再生能源实验室报告 NREL/SR-570-24860，1998 年 7 月。
18. 中国农业部，美国美国能源部，《中国生物质能转换技术发展及评价》，美国可再生能源实验室报告 NREL/SR-570-25146，1998 年 7 月。
19. M.WALSH，“中国机动车污染控制：市区的挑战”，《中国市区运输策略》，S.STARES, Z.LIU eds.，世界银行，1996。
20. 尹炼，“迎接 21 世纪中国太阳能与风能时代”，风力发电场商务发展与政策分析研讨会，中国国家电力公司，中国福霖风能开发公司及美国能源部资助，中国杭州，1999 年 3 月 15-19 日。
21. 施鹏飞，“中国风力发电场的潜在市场”，《美国风能协会风电会议论文集》，Denver Colordo，1996 年 6 月 23-27 日。
22. D.ELLIOTT，M.SCHWARTZ，《中国东南-风能资源图谱》，美国环境保护所国家可再生能源实验室，1998 年 5 月。
23. S.CHEN，《风电场分析及并网》，电力科学研究院递交给美国可再生能源实验室的报告，华盛顿，1997 年 7 月 18 日。
24. 《1997 年中国能源回顾》，国家经贸委资源节约与综合利用司。
25. William CHANDLER，GUO Yuan, ZHOU Dadi，“中国电力选择：经济及环境成本分析”，递交中国国际经济发展合作委员会，太平洋西北国家实验室，PNWD-2433 报告，1998 年 6 月。
26. 陈和平，“能源节约是中国可持续发展战略的重要部分”，《中国能源》，1997 年 10 月。
27. 能源信息办公室，《1997 国际能源展望》（华盛顿，1997 年 4 月 11 日）。
28. 科学技术部，国家发展计划委员会，《进一步支持可再生能源发展通知，（1999）#44》。
29. S.HUANG，K.ZHENG，“中国地热资源开发与利用的最新进展”，《世界地热资源会议论文集》，意大利佛罗伦萨，1996。
30. Z.LIO.，中国能源及利用，地热资源协会，21 期，1997 年 9 月/10 月。
31. Z.KEYAN，C.JINRONG，中国地热资源小区供暖的增长，世界地热资源会议论文集，意大利佛罗伦萨，1996。
32. P.ZHAO，J.JIN，J.DUO，T.LIANG，“西藏羊八井深层地热资源”，《地热资源协会》，21 期，1997 年 9 月/10 月。
33. W.FLEMING，“亚洲国家[中国]地下资源热泵设计与运行经验”，《美国加热、制冷和空调工业学会文集》，1997 年 1 月。
34. A.HOFFMAN，《新世界》，地热资源委员会刊物，总第 26 期，第 5 期，1997 年 5 月。
35. D.JHIRAD，K.LANGER，“加速中国可再生能源计划”，国际能源协会会议论文，北京，1997 年 5 月。

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