# Renewable Energy Development in China: The Potential and the Challenges


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# Part I. Overview

## *Chapter 1. Introduction*

### I. Background

China has made great strides in the last two decades in bringing prosperity to a greater share of its people. The country's Gross Domestic Product (GDP) grew by 9.6% between 1979 and 1999.[i] Older state-run industries are being replaced by a dynamic new economy.

Unfortunately, this economy requires a huge engine to run it, and prosperity has brought with it a huge cost in the form of air pollution. In 1999, two-thirds of the primary energy consumed in China was produced by the burning of coal. Even with improvements in end-use energy efficiency, energy demand continues to grow and so does the air pollution. In China, pollution is causing serious health problems, crop damage and acid rain, all of which are taking a social and economic toll. The World Bank estimates the burden of air and water pollution in 1995 to be about $50 billion or 8 percent of GDP.[ii] Seven of the ten cities with the worst air pollution in the world are in China, with pollution levels that greatly exceed World Health Organization standards.[iii] One out of four deaths in the country is due to lung disease, potentially caused by and certainly exacerbated by pollution.

**Forecast of China's Gross Domestic Product 1990-2020 (US$ Billion 1997)**

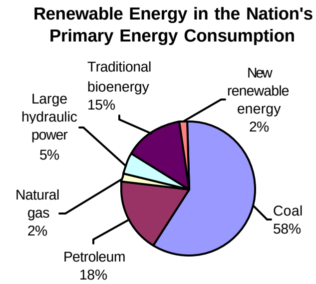
| | |
|---|---|
| 1990 | 440 |
| 1996 | 851 |
| 1997 | 926 |
| 2005 | 1,599 |
| 2010 | 2,193 |
| 2015 | 2,751 |
| 2020 | 3,761 |

Annual Increase: 6.3%

*Source: Energy Information Administration*

China is, of course not alone in this regard. Pollution levels are rising in many countries – both developing and developed. One of the key strategies many countries are studying is an increasingly reliance on environmentally sustainable renewable energy. If employed on a large enough scale, the cost of these resources could come down and eventually be competitive with traditional fossil fuels.

In terms of meeting energy needs in the 21st century, many developed countries have made renewable energy a cornerstone of their energy policies. The European Union's Energy White Paper set the goal of having 12 percent of the EU's electricity generated by renewable energy by 2010. Denmark is aiming for 35 percent by 2030. The United States and Japan have stated their intention to focus on clean and renewable energy. Some developing countries like India, Indonesia, and Brazil have also stressed the importance of renewable energy in meeting their future development needs. The Chinese Government has joined in, stating that renewable energy development will be a major component of China's basic energy strategies. China has signed a number of international treaties, including the Rio Declaration and the Framework Convention on Climate Change. The Chinese government published China's Agenda 21 and and developed "Ten Major Response Strategies on China's Environment and Development." In 1996, China published "Outlines on China's New and Renewable Energy Development for 1996-2010."




Although these efforts have spurred policy planning in the sector, actual implementation has lagged far behind. China's energy policy in the next several years will have to focus on implementation and not on general policy statements in each five-year plan. Creating real incentives for the private sector to deliver renewable energy will be the only effective way to lower the cost of technologies and have more wind, solar, biomass and geothermal facilities come on-line.

## II. Why Renewable Energy: China's Energy Challenges

Most opposition to renewable energy development comes from those who are concerned about the higher up-front cost of generation capacity. While a concerted renewables program can substantially reduce cost through competition and economies-of-scale, there are several additional benefits that can ultimately affect cost. Renewable energy development makes sense from a number of points of view, particularly with regards to energy security, international competition, employment benefits and environmental and health improvements.

### *A. Energy Security*

China became a net oil importer in 1993, and dependence on foreign oil has been increasing. In 1999, 22 percent of total oil consumption came from net imported oil, a figure that is expected to reach 40 percent by 2010. China is thus becoming more vulnerable to the uncertainty of the oil markets and to political volatility in oil producing areas of the world.

***Sectoral Breakdown***

| | |
|---|---|
| Industrial | 74.7% |
| Residential | 11.6% |
| Transport | 8.2% |
| Commercial | 5.5% |

*Source: Enerav Information Administration*

### *B. International Competitive Pressure*

With China's opening to the outside world, best exemplified by the pending accession to the World Trade Organization, domestic energy markets will be feeling the increasing pressures of international competition. Because of outdated equipment, poor management, and conflicting policies, China's energy technologies are not competitive on the international level.

In oil and natural gas, China's average production cost is higher than most other countries. The cost of finished oil products is currently higher than on the Transnational Oil Corporation, an indication that domestic oil refineries are not cost competitive. The average international price of natural gas in terms of BTU-content is twice as high as the prices of coal.[iv] In China, however, the cost is three times as high. After China becomes a member of the WTO, it will have to introduce zero-tariffs for oil and natural gas. Non-tariff barriers, such as import quotas, will also end, and large oil corporations will be entering the local market.

In the coal sector, China should enjoy great comparative advantages in terms of resources and cheap labor. Yet, the sector's labor productivity is very low. The average full attendance productivity of major state-owned mines in 1998 was only 1.6 percent that of the United states. The labor cost per ton exceeds that of the United States, despite lower labor costs. Many domestic coal mines are making no profits. Foreign coal, which is superior in quality and cheap in price, is likely to enter the southeast coastal areas.

All of these facts mean that the opening of China's domestic energy markets to foreign competition will likely lead to substantial lay-offs and other consequences. The development of an effective renewable energy industry, which for many technologies already exists in China, will help cushion the inevitable blows.

Industrial competitiveness will also likely be a victim of opening up to the world. Electricity prices for industrial consumers in the southeast coastal areas of China are higher than prices in the U.S., blunting the international competitive edge of manufactured products. After WTO accession, more foreign chemical, steel, non-ferrous metals and other energy-intensive products will enter into the China market, thus leading to slowing down or even shrinking in growth of these industries within China.

Though China has made major strides in recent years in energy efficiency, the gap between China and advanced world levels is still significant. In 1997, China's energy processing, conversion, transmission and end use efficiency was only 31.2 percent, 10 percentage points lower than advanced international levels. Of the 33 products in 11 industries, the energy consumption is 46 percent higher than advanced international levels, consuming 230 Mtce more energy.

**China's Electricity Generation (Billion kWh)**

| | |
|---|---|
| 1989 | 518.2 |
| 1990 | 550.9 |
| 1991 | 600.9 |
| 1992 | 670.6 |
| 1993 | 744.1 |
| 1994 | 816.2 |
| 1995 | 880.9 |
| 1996 | 926.0 |
| 1997 | 972.7 |
| 1998 | 1,014.0 |

*Source: Energy Information Agency*

**Table 1.1: International Comparison in Labor Productivity and Labor Cost of Coal Industry in 1998**

| | China State-owned key mines | USA | Australia | South Africa |
|---|---|---|---|---|
| Coal output, Mt | 503.5 | 927 | 219.4 | 219.3 |
| Workers, thousand | 2629 | 78 | 20.3 | 58.5 |
| Productivity t/p/yr | 192 | 11846 | 10788 | 3749 |
| Labor cost, US$/t | 4.2 | 3.8 | 10.5 | 2.9 |
| Annual wage, US$1000/p | 0.88 | 44.6 | 76.2 | 11.1 |

*Mt = million tons, t= tons and p= persons.*
*Note: One US dollar =8.3 yuan Renminbi.*
*Source: State Bureau of Coal Industry ; IEA, Coal Information, 1999 edition.*

## *C. Health and Environmental Impacts of the Fossil-Fueled Economy*

The harm done by China's energy sector is perhaps the country's most serious environmental problem. The impacts range from indoor air pollution (through solid fuel stoves) to massive air pollution in the cities to acid rain and forest and crop destruction. Rural areas still derive 57 percent of their energy used from firewood or crop stalks.[v] Firewood consumption is leading to forest destruction, greater water loss and soil erosion.

In 1998, 78 percent of China's residents burned coal or firewood. The harm caused by indoor air pollution is similar to that of smoking. In the rural areas, respiratory disease is one of the leading causes of death, claiming 1.46 million lives in 1995. It is the third cause of death in cities, taking more than 330,000 lives annually. Relative to other Asian cities, China does not fare nearly as well, as the table below shows.

***China's Rising Carbon Emissions (Million Metric Tons of Carbon)***

| | |
|---|---|
| **1989** | 610.24 |
| **1990** | 610.30 |
| **1991** | 638.74 |
| **1992** | 659.26 |
| **1993** | 711.86 |
| **1994** | 768.01 |
| **1995** | 787.62 |
| **1996** | 793.96 |
| **1997** | 785.49 |
| **1998** | 740.38 |

*Source: Energy Information Administration*

**Table 1.2 Health Impacts of Air Pollution – China and Other Cities**

| **Error! No bookmark name given.**City | Pop. -- (millions) | Premature Deaths (x1000) | Chronic Bronchitis cases (x1000) | Respiratory Symptoms (x1000) |
|---|---|---|---|---|
| *Beijing* | 7.0 | 10.3 | 81 | 270 |
| *Chongqing* | 4.0 | 6.3 | 44 | 172 |
| *Harbin* | 3.1 | 4.0 | 34 | 102 |
| *Jinan* | 2.5 | 5.0 | 38 | 135 |
| *Shanghai* | 9.0 | 3.8 | 28 | 105 |
| *Shenyang* | 4.0 | 4.9 | 38 | 129 |
| *Tianjin* | 5.0 | 5.7 | 43 | 151 |
| *Xi'an* | 3.0 | 4.1 | 35 | 106 |
| | | | | |
| *Jakarta* | 9.7 | 6.3 | 47 | 142 |
| *Seoul* | 11.3 | 2.4 | 24 | 72 |
| *Kuala Lumpur* | 1.5 | 0.3 | 4 | 11 |
| *Manila* | 9.7 | 3.8 | 33 | 98 |
| *Bangkok* | 7.5 | 2.8 | 28 | 82 |

*PRC Air Pollution: How Bad Is It? A June 1998 Report by the U.S. Embassy;*
*"Air Pollution and its Effects." World Resources Institute: http://www.igc.org/wri/wr-98-99/prc-air.htm*

About 85 percent of China's carbon emissions – ranking second in the world – were released by coal burning. Acid rain has affected more than one-third of the land in China, and the economic losses approach two percent of the entire country's gross domestic product. A study estimated that China could eliminate its need to import grain if the haze and soot over grain producing areas was reduced. Researchers believe that *haze may be depressing China's farm yields by 5 to 30 percent*. In 1990-1996, the increased $CO_2$ discharge in China accounted for over 90 percent of the increases in the world, and the result has been mounting international pressure to bring these emissions under control.[vi]

***Top Carbon Emitters – 1998 (Million metric tons of carbon)***

| | |
|---|---|
| U.S. | 1,494.60 |
| China | 740.38 |
| Russia | 405.04 |
| Japan | 288.48 |
| India | 252.55 |
| Germany | 227.51 |
| Britain | 147.37 |
| Canada | 138.46 |

*Source: Energy Information Administration*

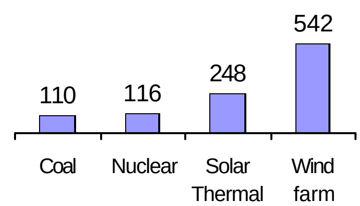
Another impact of fossil-fuel use is the heavy water requirement, an issue of particular concern in Northern China. Today, about half of China's cities face moderate to acute water shortages, and power generation is a major consumer of water. Water tables are declining and factories in the Shanxi Province have had to shut down for weeks at a time due to the lack of water, exacerbating unemployment. According to one World Bank estimate, water shortages in cities cause a loss of an estimated 120 billion yuan (US$11.2 billion) in industrial output each year. Meanwhile, a 1,000 MW coal-fired plant in Shanxi Province consumes 4.3 liters per kWh. Since coal accounts for most electricity generation in China, the water requirements and the implications of water supply are serious.

### *D. Economic Impacts*

The expansion of China's renewable energy industry has created new employment opportunities for thousands of people. According to one estimate, the existing Rmb 10 billion (US$1.2 billion) renewable energy industry provides more than 1 million jobs.

Further development of the renewables industry will provide comparatively greater economic benefit than the fossil fuel industry. Evidence from the United States suggests that renewable energy generation is more labor intensive than traditional generation. Despite this fact, the overall costs of renewable generation are rapidly declining. According to one report from the U.S. Worldwatch Institute, generating one billion kilowatt-hours of electricity from coal or nuclear fuels requires only 100 to 116 workers, while a solar thermal facility provides 248 jobs and a wind farm provides 542 jobs. Given the lower labor costs in China than in the U.S., *renewable energy will be more competitive than in developed countries*. In addition, while more labor is needed to run a renewable facility, these costs are countered by the fact that no fuels like coal or oil are required.

**Jobs Provided by Generating 1 Billion kWh of Electricity**




## III. Today's Renewable Energy Industry in China

With advances in science and technology, China's renewable energy industry has witnessed steady growth. In some technologies, notably solar water heating, China has a well-established industry with decent-sized export markets. Other technologies are rapidly moving towards commercialization. Chinese advances in some renewable energy technologies include:

* development of practical and commercialized units
* basic design/manufacturing capacity for modern and large-scale units
* establishment of national testing centers
* training of technical personnel
* new innovative technologies for development and application
* continuous improvement of equipment performance, which is approaching international standards for many technologies.

The table below summarizes where China's renewable energy technologies are today.

**Table 1.3: Phased Assessment of China’s Renewable Energy Technology Development**

| Types of Technologies | Maturity and Development Phase | | | |
|---|---|---|---|---|
| | R&D | Demon-stration | Early Commer-cialization | Commer-cialized |
| Small hydropower | | | | * |
| Solar water heater | | | | * |
| Passive solar house | | | | * |
| Solar stove | | | | * |
| Solar drier | | * | | |
| Solar cell | | | * | |
| grid-connected wind turbines | | | * | |
| Small and mini wind turbines | | | * | |
| Geothermal power generation | | | | * |
| Geothermal heating | | | | * |
| Traditional bioenergy technology | | | | * |
| Small methane tank | | | | * |
| Large & medium methane tech | | | * | |
| Municipal Organic waste power generation | | * | | |
| Biomass gasification | | * | | |
| Other modern bioenergy techniques | * | | | |
| Wave power generation | * | | | |
| Tidal power generation | | | * | |
| Ocean thermal energy conversion | * | | | |
| New hydrogen manufacturing tech | * | | | |
| Hydrogen storage techniques | * | | | |

# Part II. Electricity Generation Technologies

## *Chapter 2: Wind Power*

### I. Introduction

China has world-class wind resources. Over the past 10 years, wind power generation has developed rapidly, with the installed capacity increasing from 20 megawatts in 1990 to 224 MW by 1998.[vii] By the end of 1999, 24 wind farms provided a total installed capacity of 268 MW. This growth, however, has lagged behind Germany, Spain and India and is far behind the goal of 1,000 MW by 2000 set by the former Ministry of Energy. There are a variety of reasons for the slow development, including inadequate government incentives, slow reform of the power sector and pricing barriers

In contrast, small wind generators (100W-5 kW) are widespread in China. In 1998, 156,000 units were in operation, with the total installed capacity reaching 18.1 MW and the number of users reaching 159,000 – mostly herdsmen in Inner Mongolia. Recently, however, the growth of small units has slowed due to market saturation.

### II. The Resource Potential

There is no precise estimate of the potential for wind resources in China. Although one study puts the total at 253,000 MW (at an elevation of 10 meters), there is little clear analysis as to how much of that is economically exploitable. The offshore wind power resource is estimated at 750,000 MW. If one counts the fact that a modern turbine can exceed 50 meters in height, an elevation where the wind power density ($W/m^2$) is twice as much as it is at 10 meters, the total technical exploitable resources in the country comes to 2000 GW.

It is important to remember, however, that wind power development is restricted by many factors. The exploitable resources make up only a small part of theoretical resources. According to the U.S. Department of Energy, only 2 percent of wind resources in the U.S. are technically exploitable while the proportion of economically exploitable resources is even smaller (1/1000).

The World Energy Council's 1994 wind energy evaluation indicates that the wind theoretical resource potential in China is 17,000 TWh/year. Based on the various constraining factors, we estimate that wind power development could reach 4,000 MW by 2010, 6,000-8,000 MW by 2020 and 50,000-

100,000 MW by 2050.[viii]

## III. Small-Scale Wind Turbines Development for Rural Area

China's development of wind power started with mini and small wind generation units and gradually upgraded to larger ones. The application of small wind generators is a component in China's rural energy development. Small-scale wind is able to supply power to remote and pasture areas that are difficult for the grid to reach. This is accomplished either through on-site generation or a mini-grid arrangement.

As a result of these applications, China has developed mass production of mini and small wind generation units . Most of these products have found extensive applications in grazing areas such as Inner Mongolia, Xinjiang and Qinghai as well as fishing zones along coastal areas. In addition, small wind units ranging from 0.3 to 20 kW have also been successfully developed for small-scale uses.

Today there are 11 sizes of small wind power generators being installed in China: 50, 100, 150, 200, 300,and 500-watt; and 1, 2, 3, 6, 10, and 20-kW machines. Small wind power generators are composed of blades, turbine, gyro-rotor, tail wing, supporting pillar, batteries and a supporting pad. The blades turn the turbine and the electricity is then saved in batteries. The direct current stored in the battery can be converted into alternative current through a DC to AC converter and then transmitted to users. Such systems may provide power at different voltages such as 12 V, 24 V, 36 V, 110 V and 220 V as required.

*China's wind development could reach as high as 100,000 MW. Total capacity in China today is 277,000 MW.*

Of the 26 provinces, municipalities and autonomous regions with wind power applications, seven possess more than 1,000 small wind generator units. They are Inner Mongolia (140,000), Gansu (3,120), Henan (2,710), Ningxia (1,720), Xinjiang (1,680), Shandong (1,330) and Anhui (1,080).

Twenty-five manufacturers produce small household wind power units. . China's current assembly capacity for small wind power generator is 30,000 units per year. Major manufacturers are Shangdu Husbandry Machinery, Power Factory in Inner Mongolia and Shangxi Taiyuan 884 Factory (). Recent years have seen exports of small wind power generators in limited quantity to Southeast Asian countries, Japan, Germany and Cuba.

To meet the power needs of remote areas, experts have developed wind-photovoltaic and wind-diesel generation systems, though they remain at the experimental and demonstration stage. Sixteen sets of off-grid wind power and photovoltaic power generation systems are installed in Inner Mongolia. Experiments have shown that these technologies improve the security and reliability of power supply in remote areas.

*Small-Scale Technologies for Off-Grid Applications:* It is actually more advantageous to use small wind power technology than conventional energy supply in off-grid areas such as Inner Mongolia. Take the following example from a four-person family. Before the introduction of wind power, the family used kerosene lamps or candles for lighting, batteries for a small radio and a flashlight or Lantern for outdoor lighting – all for an average annual cost of Rmb 261. After installation of a 100-watt wind generator, annual expenditures declined to Rmb 222 under the same conditions. The new energy has not only saved herdsmen money but has improved the quality of energy supply.

**Table 2.1: Energy Consumption and Expenditures of Herdsmen**

| | Item | Annual consumption | Unit price | Total Expenditures (Yuan) |
|---|---|---|---|---|
| Illumination | Kerosene | 18 kg | Rmb 1.60/kg | 28.8 |
| Illumination | Candle | 730 pieces | Rmb 0.275/piece | 200.75 |
| Radio | Dry battery | 18 pairs | Rmb 1.05/pair | 18.9 |
| Illumination for lamb birth | Dry battery | 12 pairs | Rmb1.05/pair | 12.6 |
| Total | | | | 261.05 |

*Consolidated data from ' surveys.*

**Table 2.2: Power Supply Costs of Mini Power Generator**

| | 100W wind power generator | Battery | Maintenance | Subtotal |
|---|---|---|---|---|
| Number (unit) | 1 | 2 | -- | -- |
| Price (Yuan/unit) | 700 | 360 | - | -- |
| Life span (year) | 10 | 3 | -- | -- |
| Average annual costs (Yuan) | 70 | 120 | 30 | 222 |
| Power output (kWh/year) | -- | -- | -- | 260 |
| Power generation costs ( Yuan/kWh) | -- | -- | -- | 0.85 |

*Consolidated from surveys. Bank interest is not taken into account.*

**The Obstacles Facing Small-Scale Wind Power Development:** In China, the sale of smaller wind power units has slowed. Some of the reasons include:

* **Weak purchasing power and market demand*: Despite the strong need for power in rural areas and the constraints on local development caused by the lack of electricity, the low***

***income of local people and limited local government budgets have hindered the extension of new technologies.  Per capita income in Inner Mongolia, for example, is about 1,700 Yuan.***

* ***A 200-watt wind generator costs about 2,000 Yuan – almost the entire income earned by a herdsman in a year.  As a result, only 20 percent the local population can afford to buy a 200-watt generator, and less than 12 percent can pay in cash. Moreover, the average income of farmers and herdsmen in the Northwest China and the Henan province is even lower than in Inner Mongolia.***

* **Lack of local government funds*: Being strained for resources, local government are unable to provide a substantial amount of help.  For example a wind- diesel-batteries system requires an initial investment of 25,000-64,000 Yuan/kW.  A wind-photovoltaic system requires 70,000-90,000Yuan/kW.  Obviously, it is difficult for the town and villages' government and individuals to support such a high capital investment.***

* **Short life of wind power generators*: Chinese-made wind generators have a life shorter than their foreign counterparts. Foreign-made units can last for 20 to 25 years.  China's small wind generators have a design life of 10-15 years, and the system may not last even that long.***

* **Maintenance*: Chinese users are often not aware of the maintenance these systems may require.***

## IV.  Grid-connected Wind Power Development

In the 1990s, China started work on medium to large wind generators, ranging from 120 kW to 600 kW.  China has also strengthened research efforts on system design, installation, blade-manufacturing and system control.

To strengthen China's wind power industry the country turned to long-term cooperation with foreign companies.  In 1986 Shandong Rongcheng imported three Danish Vestas 55 kW wind turbines to create China's first wind farm.  China has so far imported nearly 1,000 wind generators with an installed capacity of over 200 MW through technology trade, inter-governmental cooperation and joint ventures. China has also established ten 10 MW grade wind farms and started seven joint venture enterprises (albeit very small ventures). These efforts will no doubt improve China's research and development capacity for large wind turbines. The current status of China's wind development and manufacturers is given in the tables below.[ix]

**Table 2.3: Installed Capacity Distribution of China's Wind Farms**

| *FACILIITY* | *CAPACITY (MW)* |
|---|---|
| 1. Hebei Zhangbei Wind Farm | 9.8 |
| 2. Inner Mongolia Zhurihe Wind Farm | 4.2 |
| 3. Inner Mongolia Xilinhaote Wind Farm | 30.7 |
| 4. Inner Mongolia Huitengxile Wind Farm | 1 |
| 5. Inner Mongolia Shangdu Wind Farm | 3.875 |
| 6. Liaoning Donggang/Hengshan Wind Farm | 17.2 |
| 7. Zhejiang Hedingshan Wind Farm | 10.2 |
| 8. Zhejiang Sijiao Wind Farm | 0.3 |
| 9. Shandong Rongcheng Wind Farm | 0.165 |
| 10. Hainan Dongfang Wind Farm | 8.755 |
| 11. Shandong Changdao Wind farm | 0.11 |
| 12. Guangdong Nan'ao Wind Farm | 42.43 |
| 13. Fujian Pingtan Wind Farm | 1.055 |
| 14. Xinjiang Dabanheng Wind Farm | 64.1 |
| 15. Jilin Tongyu Wind Farm | 7.2 |
| 16. Shanghai Zongming Wind Farm | * |
| 17. Jiangsu Qidong Wind Farm | * |
| 18. Zhejiang Linhaiguocangshan Wind Farm | 19.8 |
| 19. Jiangxi Panyanghu Wind Farm | * |
| 20. Guangdong Shantou Huilai Wind Farm | 12 |
| 21. Gansu Yumen Wind Farm | 1.2 |

**Not yet in operation*

*Source: From information presented at the Workshop on Wind Energy Development for China in the 21st Century.*

**Table 2.4: Major Domestic Large Wind Power Generator Manufacturers**

| ENTERPRISES | BASIC STATUS |
|---|---|
| Danish NEG MICON – Inner Mongolia Wind Power Co. | Founded in 1996, joint venture, mainly assembling of 600 kW generators and tower |
| Danish MICON-Zhejiang Power Equipment Manufacturer | Founded in 1996, mainly assembling of large wind power generators. Up to date 17 have been produced. |
| German NORDEX-Xian Aviation Generator General Co. | Founded in 1997, joint venture designing and manufacturing large wind generators -- 600 kW and 250 kW wind generators. Designed capacity for 140 units per year, unrealized for technical and market reasons |
| German HSM-Luoyang No.1 Tractor Co. | Founded in 1994, joint venture designing and manufacturing large wind generators such as 250 kW wind generators. Ten units produced in 1995 with full German technologies. The planned 60 units output unrealized as the result of fund shortage. |
| Spanish Lude-Luoyang No. 1 Tractor Co. | Founded in 1998, joint venture designing and manufacturing 600 kW wind turbines; plan to produce 2X600 kW generators in 1999 with a localization rate reaching 70 percent. |
| Beijing Wandian Co. Ltd. | Founded in 1996 with Austria PEHR, designing and manufacturing large wind generators. Purchased one FLODA636 sample generator. Prototype unit produced in 1998 with Chinese blades and tower and remained in operation in Huitengxile Wind Farm. Planned to produce 10 units in 1999 and 30 units in 2000. |
| Xinjiang Wind Energy Co. | Its subordinated wind farm was located in Xinjiang Dabancheng. At the end of 1998, its installed capacity reached 40 MW. Through more than a decade operation, rich operational and maintenance experiences were accumulated with strong technical strength. In 1997 it purchased designing technology of Jacobs 600kW. At present, Chinese made Jacobs unit is working smoothly in Dabancheng. Its generator, gear box and yawing system are all Chinese made with the components such as blades, high speed brake, hydraulic system and safety mechanism imported. |

In addition to the companies listed above, other enterprises are engaged in manufacturing large or medium wind turbines, gear boxes, control system and towers:

* *Turbine Manufacturing:* Hangzhou Power Generator Manufacturer, Xiangtan Power Generator, Lanzhou Power Generator and Shanghai Power Generator.

* *Gear Box, Control Systems and Tower Manufacturing:* Hangzhou Gears, Sichuan Gears, Nanjing High Speed Gear Box and Xian Aviation Generator; Nanjing Institute of Automation produces control system and Ruian Pressure Container, Guangzhou Shipyard and Anshan Iron Tower produces towers.

## V. Obstacles to Further Wind Power Development

### *A. Price Barriers*

While the life-cycle cost of renewables is close to competitive with conventional sources of power, up-front costs are indeed higher. As with most countries, wind-generated electricity in China is more costly than power generated by coal. The table below illustrates several examples in different provinces. It is estimated, however, that the wind power cost may drop to 0.32 yuan/kWh (4 US cents/kWh) by 2010, at which time it would compete with electricity generated by coal.

**Table 2.5: Prices of China's Wind and Coal Power**
**Unit: yuan/kWh of scale to network**

| | (1) Wind power | (2) Coal power | (1) / (2), percent |
|---|---|---|---|
| Xinjiang | 0.70 | 0.32 | 218 |
| Inner Mongolia | 0.71 | 0.35 | 202 |
| Liaoning | 0.95 | 0.45 | 211 |
| Shandong | 0.80 | 0.45 | 178 |
| Zhejiang | 0.79 | 0.50 | 156 |
| Fujian | 0.79 | 0.55 | 143 |
| Guangdong | 0.77 | 0.60 | 132 |

*Source: Zhao Jiarong, Eds. Study of China's Economic Incentive Policies for Renewable Energy Development, China Environmental Sciences Publishing House, Oct. 1998.*

One reason for the high cost is the need to import larger-scale and more advanced technologies from Western countries. Through joint ventures or through more research and improved designs, China could develop a domestic capacity to produce larger generators at reduced costs.

In addition to high initial capital costs, the relatively low capacity factor discourages investment in large wind generation. Finally, it is important to note that wind energy in China is more expensive than wind in other countries. The high cost of importing equipment – tariffs, value-added taxes, shipping and installation – contributes to the 0.60 Yuan/kWh cost. This is about 60 percent higher than in countries with mature wind power industries.

**The Higher Costs of Wind Power in Perspective**

As shown by this example, the current cost of grid-connected wind power including value added tax could be as high as 0.951Yuan/kWh (11.45¢/kWh) in the period of repayment of both principal and interest. The costs would decrease at 0.37 Yuan/kWh (4.45¢/kWh) after the loan payment period. ***In this context, the average life-cycle cost would be 0.472Yuan/kWh (5.68¢/kWh).*** The basic assumptions for cost calculation are:

Full load power generation hours: 2500h/year
Capacity Factor: ~ 30 percent

Initial investment: 8300Yuan/kW, of which
- Equity capital investment 20 percent
- Domestic commercial loans: 80 percent
- Domestic commercial loan interest: 7.56 percent
- Debt service period: 7 years

Annual operational costs: 5 percent of the total investment
Depreciation of wind power generator: 12.5 years
Value added tax: 17 percent

Many Chinese experts believe that increased local production of wind power generators and expanded production scale could cause the costs of wind generation decline remarkably. Based on the experience in other countries, costs could decrease to 0.32 Yuan/ kWh by 2010 and to 0.22Yuan/kWh by 2030.

The experience in other countries has shown that competitive pressures and properly structured policies can bring down the prices of wind power significantly. For example, the United Kingdom implemented a program that set out an overall capacity target for renewable energy. Through competitive bidding, the bid price of wind, landfill gas and other renewable resources in the U.K. on a per kilowatt-hour basis was reduced by as much as 75 percent. To cite one example, the cost of wind power went from 10 pents/kWh to 2.88 p/kWh in about seven years (1.08 yuan/kWh to 0.376

yuan/kWh). The decline in price occurred because contracts were generally awarded to the lower bidders, providing an incentive for renewable energy developers to find ways to lower costs. As the tables in the Policy Section indicate, this is true for all renewables – not just wind.

### *B. Other Pricing Issues*

It is not just the higher cost of wind that is a problem, but also pricing policy in general. Currently, utilities have to obtain approval from the central government to raise prices, but tariffs are set somewhat arbitrarily and do not necessarily correspond to the cost of production. Thus, a utility investing in wind power may not be able to pass on the slightly higher costs to consumers (at a minimum, there would be a time lag until the higher tariffs were approved). This means that any investment in premium power reduces cash flow in the short term. Utilities will reject projects for which they cannot recover costs because it will eat into their earnings. In practice, utilities are refusing to buy power built by renewable generators in their service territory even though they are technically required to do so by law.

Compounding the problem is the fact that the costs for premium energy investments are often not spread across the entire province. Local distribution companies on the county or city level may bear all of the costs for wind power built within their jurisdiction, and that is a high burden, particularly for large-scale wind farms of 100 MW or more.

To increase the wind power market, the former Chinese Ministry of Electric Power published, as early as 1994, a policy to encourage wind power. The policy set out a grid-connected wind power tariff, calculated on the production cost plus the repayment of principal/interest plus a reasonable profit. The regulation would appear to encourage wind projects, however it is not clear if the law applies to independent power producers. The central utility authorities argue it only applies to them.

Thus since the utilities do not want to invest in wind power, none gets built. Central utility authorities can refuse to sign power purchase agreements with independent wind developers. In some cases, the local utility may sign a power purchase agreement for 100 percent of the wind project's output. In the fine print, however, the utility will pay the negotiated premium price for only a few kWh and pay only the average system price for the rest of the output. No wind developer could make a profit under these conditions.

### *C. Government Policy and Development of an Indigenous Industry*

The Chinese government's economic incentive policies and measures for developing wind power are the weakest among the major wind power countries. Many experts believe this is the single most important obstacle facing the wind industry.

In the United States and Europe, research and development efforts were combined with various policies to have the effect of encouraging the creation of many wind power companies. These policies, such as production tax credits, soft loans and extensive resource assessments, meant that financial institutions and investors gained confidence in the emerging wind market. China needs to explore how some of these policies might be applied to China.

*The cost of wind power could be cut by 15 percent if large wind generators were made in China and not imported.*

The ultimate goal of these policies is to create a domestic industry for wind power. The total reliance on imported large wind generators has led to high capital costs and high risks, benefiting only foreign wind generator manufacturers.

Imported generation units from countries such as Denmark, Holland, Germany, Belgium, Spain and the U.S dominate the current Chinese wind power market. Many of these countries have provided discount loans for Chinese wind power projects. The precondition for getting the loan is the purchase of generators from the Western countries. Domestically made wind generators have no tax relief or price subsidies. Although the State Development and Planning Commission and Ministry of Science and Technology have promulgated policies to support wind industry development, these policies have not been implemented.

Despite the relatively strong small-scale industry, China is not yet in a strong position to manufacture large wind power generators of 300 kW or larger, especially technological components such as blades and control systems.

Not surprisingly, foreign companies more often than not provide only general manufacturing technologies such as for tower and basic components rather than the above mentioned key technologies. As a result, China's overall capability manufacturing wind generators is far behind the international level. Because of uncertainty in the Chinese wind market, most foreign wind power companies are hesitant to invest in large-scale production for joint ventures that would encourage more technology transfer. It is simply perceived to be too risky an investment.

Recently, however, there have been some modest changes in this situation. Chinese-made components of 300 kW wind generators recently passed government quality checks. The Chinese have also made progress on producing the more complicated control systems for turbines. The local content level of some 600 kW prototype wind generators has risen to 78 percent. Despite the quality problems of domestic components, some Chinese technology is proving to be successful in actual operation.

### D. Capacity of the Electric Grid

Because wind generators work intermittently, some utility experts believe that the proportion of installed capacity of wind power in the total grid should not exceed 10 percent. China's power grids in regions of rich wind power resources tend to be small. For 1998, the grid capacity was 3,957 MW in Xinjiang, 2,302 MW in Ningxia, 3,241 MW in Qinghai and 7,803 MW in Inner Mongolia. If this assumption proves to be true, the ability to develop wind projects in the resource-rich areas would be severely constrained to less than 2000 MW. In addition, it is not clear how strong the transmission systems are to transmit the power to other regions. For example, a dramatic increase in wind development in Inner Mongolia could best serve the high-demand regions, such as Beijing. However, there has been relatively little analysis on the ability of the transmission system to handle the transmit of electricity between the regions.

### E. Weak Resources Assessment Capability

China's wind power resource assessment capability is somewhat lower than in other countries. During the Eighth Five-Year Plan period, the Chinese Academy of Meteorological Sciences launched the extensive survey of wind power resources in the country on the basis of data collected by 2,000 meteorological stations. It mapped out the general distribution of wind power resource potential and average wind speeds at different heights in different areas. And with the interest from foreign businesses, wind power resources assessments in Xinjiang and Inner Mongolia are fairly decent.

Other regions of the country, particularly the coastal areas, will require more extensive resource assessment. And regardless of the current level of data, a very detailed assessment – with a year's worth of data – is required for site selection.

It will be difficult, therefore, to see a big increase in the development of China's wind power industry without the improvement of China's wind resource investigation capability.

### F. Lack of Financing

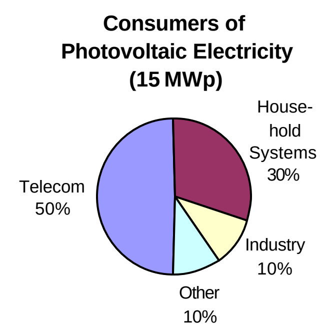
The wind industry also finds it difficult to obtain financing. Because the market is not mature, the risks are perceived to be high, and banking institutions are not willing to lend money. Most domestic enterprises and banking institutions don't know much about wind generation, and the wind industry is an emerging business with limited experience. Lack of financing has become a major factor in restricting the growth of the wind market.

# Chapter 3:  Photovoltaics

## I.  Photovoltaic Technology

China began to develop solar power technologies in the 1970s.  Today, the government is completing several demonstration projects, and there are preliminary plans to build solar generating facilities in Tibet with a total installed capacity of 100 MW.

### A.   Market Overview




China produced 3 MWp of photovoltaic cells in 1999, and the total cumulative amount in operation was 15 MWp.  Only about one percent of the 15 MW is attached to the grid.  Of this, 50 percent was used by telecommunication projects.  By 1997, for example, half of Tibet's 889 townships had PV-based satellite land receiving stations.  Thirty percent were household systems, and 10 percent were used by industry.

The average selling price of PV panels and components alone was 42 yuan/Wp, or about US$5/Wp, higher than the average price on the international market.  The high price is mainly attributed to the high manufacturing cost of components.  When the entire system is considered (including the battery), the most common current household photovoltaic systems of 20  Wp, 38 Wp and 50 Wp sell at  1850 Yuan, 3500 and 4200 Yuan respectively.  The average price per watt is 84-92 Yuan.

Despite the higher prices, sales of photovoltaic cells on the domestic market have been growing annually by 20 percent in the past few years.  And all evidence suggests that prices will drop, further increasing the potential market.  According to the learning curve of WEC/IIASA, costs could be lowered by 20 percent when the sales of photovoltaic cells double (See table 3.1).

International aid, particularly for off-grid, household systems, should also expand the market and further bring down prices.  In 1999, the World Bank/GEF donated US$25 million, which was used to build 200,000 solar home systems (SHS) with a total capacity of 10 MW.  The Danish government donated to Xinjiang 100,000 SHS, valued at US$15 million.

**Table 3.1: Forecast of selling prices and power generation cost of PV power system**

| | 1999 | 2010 | 2020 |
|---|---|---|---|
| Selling price of PV system, yuan/Wp | 65 | 30-40 | 14-28 |
| Power generation cost, yuan/kWh | 2.3 | 1.1-1.4 | 0.5-1.0 |

Due to the rise in oil prices and internalization of environmental costs, the cost of power generation using fossil fuel is anticipated to rise. If these projections prove to be correct, some Chinese experts have estimated that PV power could compete with conventional technologies before 2020.[x] Under this scenario, it is forecast that by 2010 China's installed capacity of photovoltaic power generation will reach 150 MWp. By 2020, that figure could rise to 4-8 GW.[xi]

**Table 3.2: Price Forecast of China's Fossil Fuel**

| | 1999 | 2010 | 2020 |
|---|---|---|---|
| Coal used in power generation, US$/Gj | 1.67 | 1.85 | 1.94 |
| Coal, US$/t | 40 | 42 | 46 |
| Petroleum, US$/bbl | 15 | 17 | 25 |
| LNG, US$/toe | 126 | 141 | 210 |

*Note: The currency value of coal used in power generation is that of January 1996 and the rest is the currency value of 1990.*

*Sources: APEC, Coal and Natural Gas Competition in APEC Economies, August 1999, Bangkok; IEA, World Energy Outlook, 1998 edition, IEA/OECD, Paris.*

### *B. Domestic Manufacturing*

A long tradition of research and development puts China in a strong position for domestic PV development. More than 40 companies and institutions are involved in solar cell research, development and manufacturing. PV manufacturing techniques have steadily advanced with major progress in the research and development of basic materials. .

*In the near future, demand for photovoltaic equipment is going to be higher than can be met domestically.*

In the 1970s, China's earliest PV cells were single crystal with an efficiency of only 8-10 percent and a price as high as 400Yuan/Wp. With a good deal of research, China has developed better single crystal solar cells that are today dominating the domestic market. Newer PV cells have a higher efficiency of 12-13 percent, two points less than the internationally advanced level of 14-15 percent. Today, costs have also been reduced by 45 percent, basically in line with imported cells. We should see, therefore, continuing drops in the cost of PV products in China.

To further reduce the costs and improve the efficiency, research organizations have carried out several studies on non-crystal thin film cells, CIS solar cells, CdTe thin film cells, multiple crystal thin film cells and high performance single crystal solar cells. Low cost, non-crystal cells have reached mass production, and multiple crystal cells have reached trial production. At present, the conversion efficiency of 30 X 120 mm P-i-n non-crystal solar cells can be stabilized at 4-6 percent with the one of 100 X100 mm reaching application level at 10-11 percent.

Despite progress in domestic manufacturing, most experts predict that in the next decade, imported technologies will capture 20 to 25 percent of the market, primarily because of the limited production capacity and increasing demand. The most pressing problem is the high cost and insufficient production capacity for silicon chips. At present China has seven plants producing solar cells with an annual designed production capacity of 4.5 MW – although actual production is much less.

## II. Photovoltaic Products

The high capital cost of PV technologies is a problem in any country, but particularly so in China because of a lower average income. At present the average cost of China's solar cell component is around 28 Yuan/Wp with an average sale price at 42 Yuan/Wp. With the supporting equipment, the whole system may cost as much as 40-60Yuan/Wp, several times higher than technologies for similar applications (such as diesel systems and other off-grid and distributed energy approaches). Major factors contributing to the high production cost are as follows:

* Small production scale. The actual production capacity of China's major solar cell component manufacturers is 0.5-1MWp/year; ten to twenty times lower than that of their overseas counterparts (5-20MWp/year).

* Outdated production facilities and techniques;

* Importation of some raw materials;

* Importation of silicon wafers because of insufficient domestic supply;

* An increasing gap in terms of production cost, efficiency, finished products, automatic production and technological reliability of China's single crystal silicon cells compared to their overseas counterparts.

*Non-standard System Design and Uneven Quality Control:* There are no standards for system size, for the modules and switching components or for appearance. A manufacturer does not have to assure any level of quality, so many potential buyers are concerned about the system's reliability.

*Battery Problems:* The components of a photovoltaic generation system includes, in addition to the PV cells: batteries, reverser, a controller and dc lights. The batteries used by solar energy consumers are generally closed lead-acid batteries, automobile or motorcycle batteries. More expensive and better-quality industrial batteries are generally not used. At the present time, no lead-acid batteries with deep discharging and a long life span are available for PV systems. While many companies produce vehicle batteries, their quality is inconsistent with a maximum life of 3 years. Battery lose efficacy is a major problem in the expansion of the use of solar energy systems.

China has also been consistently poor at manufacturing controllers, reverser and dc lamps, especially in the following aspects:

* Under-scaled production;

* Uncoordinated quality standards;

* Small-scale production with high cost and poor quality;

* Product development uncoordinated with market demand;

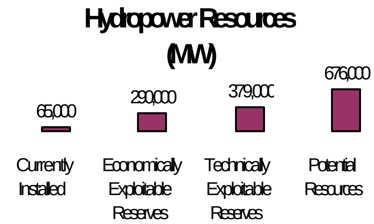
* Poor quality components and connectors

* Slow market development and weak promotion

*Market Development:* China's large population could be a huge market for solar electric equipment. The photovoltaic market has expanded but investment is mainly confined to special market sectors such as telecommunications and off-grid applications. As a result, the market growth is slow though some overseas institutions or businesses have shown recent interest in China's photovoltaic market.

In addition to the World Bank and Danish projects, some businesses in Japan, U.S. and Europe have made contributions. Their objective is to open the Chinese market and promote the development of China's photovoltaic industry. Facing the dual pressure of energy and environment needs, China's photovoltaic industry should accelerate its pace to meet this challenge.

## *Chapter 4: Hydropower*




With some of the largest and most famous rivers in the world, China is rich in hydropower resources. Potential hydropower development in China is as high as 676,000 MW. The technically exploitable reserves are estimated to be 379,000 MW, and the level of resource considered to be economically exploitable is about 290,000 MW, or 1,260 TWh – *more than China's total generation capacity in 1998.*

In 1998, China's total installed hydropower capacity was 65,000 MW with an annual power output of 208 TWh, accounting for less than one quarter of the economically exploitable resources. The installed capacity is expected to reach 110 GW by 2010, 160-180 GW by 2020 and 260-290 GW by 2050. The power output is expected to reach 350 TWh by 2010 and 500-563 TWh by 2020.

### I. Medium and Large-sized Hydropower

In 1998, China had 40,000 MW large and medium-sized hydropower, providing an annual power output of 128 TWh. Another 31,800 MW is under construction. With the Three Gorges project underway, China ranks first in the world in the construction of hydropower.

The capacity added in 1999 was 6,300 MW. The Ertan Hydropower Plant on the Yalong River, a tributary of the Jinsha River in Sichuan Province has a designed installed capacity of 3,300 MW. It was completed on December 4, 1999 and is the largest hydropower facility built in the 20$^{th}$ century. The Lijiaxia Hydropower Station on the upper reaches of the Yellow River in Qinghai Province has an installed capacity of 2,000 MW. It was completed on December 3, 1999. The Guangzhou Pump Storage facility, with an installed capacity of 2,400 MW, was completed on March 14, 2000.

The well-known Three Gorges Project with a designed installed capacity of 18,200 MW was started in December 1994 and closure of the river was completed on November 8, 1997. The first generating unit is expected to come on line by 2003, and the whole project is scheduled to be completed by 2009.

**Table 4-1: Large Hydropower Stations Completed or Under Construction (over 1,000 MW)**

| Name | Location | Installed capacity, MW | Year of operation and completion |
|---|---|---|---|
| Three Gorges | Hubei | 18200 | 2003,2009 |
| Ertan | Sichuan | 3300 | 1998, Completed in 1999 |
| Gezhouba | Hubei | 2715 | 1981, Completed in 1988 |
| 1st,2nd phases of Guangzhou pump storage | Guangdong | 2400 | 1993,Completed in March 2000 |
| Lijiaxia | Qinghai | 2000 | 1997, Completed in 1999 |
| Xiaolangdi | Henan | 1800 | In progress |
| Tianhuangping | Zhejiang | 1800 | 1997,completed in 2000 |
| 1st,2nd phases of Baishan | Jilin | 1500 | 1983, Completed in 1994 |
| Shuikou | Fujian | 1400 | 1993, Completed in 1996 |
| Dachaoshan | Yunnan | 1350 | In progress |
| Tianshengqiao, 2nd stage | Guizhou, Guangxi | 1320 | 1994, Completed in 1998 |
| Longyangxia | Qinghai | 1280 | 1987, Completed in 1989 |
| Manwan | Yunnan | 1250 | 1993, Completed in 1995 |
| Yantan | Guangxi | 1200 | 1992, Completed in 1994 |
| Geheyan | Hubei | 1200 | 1993, Completed in 1994 |
| Tianshengqiao, 1st stage | Yunnan,Guizhou, Guangxi | 1200 | in progress |
| Wuqiangxi | Hunan | 1200 | 1994, Completed in1996 |
| Liujiaxia | Gansu | 1160 | 1969, Completed in 1974 |
| Wanjiazhai | Shanxi | 1080 | 1998, completed in 2000 |
| Fengman | Jinlin | 1004 | 1943, Completed in 1998 |

*Source: China Power, No. 10, 1999.*

## II. Small hydropower[xii]

In China, small hydropower refers to a station with an installed capacity of less than 25MW. The theoretical resources for small hydropower are 180,000 MW and the technically exploitable resources are 75,000 MW.

In 1998, the installed capacity of small hydropower reached 25,200 MW and output reached 80 TWh, accounting for about 39 percent of the total hydropower installed in China. The average electricity price of small hydropower is 0.32 yuan/kWh.

The total installed capacity of small hydropower stations may reach 35,000 MW and output may reach 112 TWh by 2010. By 2020, there could be 50,000-55,000 MW, and 160-176 TWh of output.

As far as the industrial scale is concerned, small hydropower generation is the largest and fastest growing renewable resource in the country. At the end of 1997, 22,000 enterprises were involved in small hydropower – with nearly 1 million employees. Being a major component of China's power industry, these enterprises have fixed assets worth Rmb 82.1 billion. Small hydropower provided power to one third of the counties and 300 million people – one quarter of China's population. About 782 counties rely primarily on small hydropower for their electricity supply.

The government believes that development of small hydro facilities is an important way for China to promote rural electrification. The government has adopted a series of incentive policies for developing small hydro, such as the granting of preferential loans and reducing the VAT on electricity sales from 17 percent to 6 percent.

China also leads the world in the export of small hydropower equipment.

*While Three Gorges gets all of the attention, China has the potential to develop up to 75,000 MW of small hydro – dams less than 25 MW.*

## III. Mini-hydropower

Mini-hydropower refers to facilities with an installed capacity of 0.1-10kW. Potential resources are estimated at 80,000 MW, mainly scattered in hilly areas around South China. Mini-hydro power plants use small rivers with a drop of 1.5-30.0 meters and a flow of 15-500$m^3$/h. These facilities mainly supply power to rural households or small villages for lighting, home appliances, and small farm processing machines.

Mini-hydropower is the innovation of the development of renewable energy in rural China. The total installed capacity by 1998 reached 163.6 MW. Output reached 271.8 GWh, and the number of household totaled 566,000. According to the Ministry of Agriculture, total installed capacity of mini-hydro is likely to reach 6,400 MW by 2010.

## IV. Role of Hydro in Renewable Energy Policy

As China is considering policies to promote renewable energy, it is important to consider the role of large hydro development in these policies. In Europe and other countries, the major purpose of renewable energy policies is to provide a market boost to resources/technologies that would not otherwise be developed or would develop much more slowly due to their market immaturity. Although some forms of hydro are not currently economic on a direct cost basis (i.e., some small and micro-hydro), large hydro technologies have been around for decades and have little if any cost-reduction potential compared to the other less mature renewables.

Hydroelectricity is one of the most common sources of power and is familiar to all levels of the electricity sector. Thus it would seem unnecessary for the government to include large hydropower construction in renewable energy development programs because this technology does not need the support these policies would provide, and it would overwhelm the ability of other technologies to benefit from the programs. Small hydro, wind, solar and some biomass technologies, on the other hand, do require government policy support.

## *Chapter 5: Biomass*

### I. Introduction

Biomass is perhaps the most cost-effective renewable resource in China, and its commercialization is a major priority for the government. Estimates of the country's biomass potential come to about 700 million tons of coal equivalent (Mtce). This includes 120 Mtce of crop stalks, 90 Mtce of firewood, and other resources making up the rest. Firewood consumption in 1998 was 100 Mtce, an estimated 11 percent beyond sustainable use.[xiii]

*Biomass is probably the cheapest renewable energy resource in China.*

In the future, however, all kinds of biomass resources will likely increase dramatically; with crop stalk use doubling between 1995 and 2010 and municipal solid waste use rising by 160 percent.

One challenge in China is its large population but comparatively small amount of land suitable for cultivation. Irrigated farmland is shrinking, in part because the government wants to return farmland to forests and in part because heavy irrigation and declining water resources are forcing farmers to cut back. The prospect of more urban migration and less farmland means there could be an increase in the amount of exploitable biomass.

### II. Biomass Power Technology

In 1998, sugar cane slugs (bagass) were used to generate 800 MW of electricity. With 164 centralized gas demonstration projects – using crop stalks at the village level – total gas production came to 45 million $m^3$, none of which is now used to generate electricity.

The potential for biomass power in China could reach 3 GW by 2010 and 10-15 GW by 2020.

**Table 5.2: Calculation of Plant Biomass in China**

| Type of Biomass: | Area: |
|---|---|
| Woodlands Biomass | 1.86 million $km^2$ |
| Cultivated Land Biomass | 1.395 million $km^2$ |
| Grasslands | 2.79 million $km^2$ |
| Rain Forest/Monsoon Forest/Tropical Forest | 1.209 million $km^2$ |

*Source: "China's Ecosystem." Martin Schultz, Guodong Sun, Shalini Vajjhala, Kristen Williams; September 30, 1997.*

## III. Other Biomass Technologies

### *A. Gasification Technology*

Stalk gasification supplies for households appeared in the last decade. From the first device developed by Shandong Provincial Institute of Energy, ten institutions in the country are now engaged in this research with four major technologies developed: fixed bed reactor (upper suction or lower suction types); fluidized bed reactor; air flow (cyclone) bed reactor; and retorting reactor. The working medium can be air and oxygen or air and steam vapor. Raw stalks of corn, sorghum, soybeans, tree branches, sawdust, barks and husks can also be used.

In addition to household gas supply applications, the technology can be used for timber drying and tea baking, as well as boiler heat supply and power generation. At present, only rice-husk fueled generation has approached a relatively mature stage, and the technology is now exported to Southeast Asian countries. Reactoring gasification systems have been successfully developed in Dalian.

Fixed bed gasification technology has experienced rapid development with 150 demonstration units in the country using $200m^3$/hour to $500m^3$/hour systems. The major problems are with gas purification and transmission. Fluidized-bed and air-flow bed technologies are still in the development process and need further testing.

### *B. Urban organic waste treatment technologies*

According to the World Bank, the waste output from China's cities is currently 140 million tons per year, which is increasing at an annual rate of 10 percent. Industrial solid waste adds another 620 million tons per year. By 1998, 6.6 billion tons of untreated solid waste had accumulated, occupying 55,400 hectares of land. National authorities estimate methane emissions from municipal waste to be in excess of 1 million tons per year. Those methane emissions will increase as China's municipal wastes and their organic content increase. Most agree that methane emissions from landfills will rise steeply in the next few decades being one of the fastest growing sectoral sources of greenhouse gases in China. The country has little experience with solid waste management or sanitary landfill practices, which are used at only eight percent of all sites. Most of China's waste sites are open pits located on the urban fringes, in stream or river valleys or on “marginal lands” such as wetlands where mixed municipal wastes are deposited.

In 1992, China set a goal to dispose of 60 percent of municipal refuse in sanitary landfills by the year 2000. China's Agenda 21 Action Plan calls for new regulations to improve the handling of municipal solid waste. More recently, the National Environment Protection Agency amended the China Trans-Century Green Program and allocated Rmb 8.8 billion for solid waste management (US$1.06 billion).

Methane extraction from solid waste landfills in industrialized countries is a mature practice. Gas from a New York City landfill is upgraded to pipeline quality and used to provide the energy equivalent to heating 10,000 homes. Since 1987, a Los Angeles landfill has produced enough gas to provide several million kWh per year of electricity. U.S. policy also encourages landfill gas recovery. There has been a tax incentive in place in the U.S. for several years for each unit of energy recovered, and soon gas recovery will be mandated for certain landfills.

*Landfill gas could be particularly important for China because it is one of the few renewable resources located near urban centers.*

Methane recovery projects are now common in Germany, the U.K., Sweden, France, Denmark, Japan, Brazil, and Chile. Landfill gas could be particularly important for China because it is one of the few renewable resources located near urban centers. The barriers to developing this resource are discussed in the next section.

## IV. The Obstacles To Greater Commercialization

### *A. Urban Wastes*

The main barrier impeding landfill gas development is technical – appropriate practices for methane capture have never been used in China. Lack of access to information on the technology and lack of experience with the design, construction and operation of gas recovery plants are major problems. The high cost of imported technology is also a factor. In order to build an industry for landfill gas, China needs experience with pipe design, layout, moisture removal and management of surges in gas supply.

The second issue is the lack of clarity about who owns and is responsible for the resource. The framework for how the municipal, provincial and national institutions should cooperate with private industry is not set. Specific laws on the regulation of landfill gas plants have yet to be fully and systematically developed. Overcoming these barriers will be critically important.

To address these obstacles, the Global Environment Foundation is undertaking three pilot methane recovery facilities in Anshan, Maanshan, and Nanjing. In addition to financing the construction of the plants, the program will work to clarify the ownership and regulatory issues.

The project is also strengthening the Beijing Environmental Research Institute and creating a permanent National Center for Methane Recovery Research and Dissemination. This facility will be the primary means for training personnel from cities seeking to build methane recovery plants. This work will go a long way in improving the prospects for commercializing landfill gas development.

In addition to landfill gas recovery, garbage can also be burned directly to provide electricity. As with other technologies, however, a number of obstacles stand in the way of waste incineration:

* The low collection rate of urban garbage provides a very limited resource for power utilization. Many waste dumps are very small and are not desirable for commercial power development;

* Due to limited experience, China's initial projects used unproven technologies and provided little useful data.

* There has been a lack of incentive and waste management policies. As a result, it is difficult to mobilize the initiatives of domestic and overseas investors for garbage disposal on an effective basis, which is a major factor slowing down the development of garbage power.

* Direct burning of trash raises a number of environmental and health issues. Waste incineration has met with much public opposition in other cities around the world.

### *B. Opportunities for Medium and Large Methane Projects from Organic Waste*

With the success of household methane digester applications, China has also developed generation facilities using methane from poultry farm waste and some industrial waste. At the end of 1997, more than 700 large and medium sized gas projects were operating in China. About 530 of these were poultry dung projects, and 172 utilized industrial wastes. Their combined capacity is about 410,000 cubic meters, processing about 20 million tons of organic waste annually. The biogas services 84,000 households, replacing coal generated electricity and heating fuel.

At present there are more than 6,000 medium to large dairy, livestock and poultry farms in China – with 800,000 tons of wastes and wastewater discharged every day. Only about 10 percent of these wastes are treated with methane technology. Many of the other farms are simply too small to use methane engineering technologies cost-effectively.[xiv] In many cases, however, there are ample untapped resources that can be economically viable.[xv]

**Table 5.3: Prediction for China's Livestock and Poultry Breeding Volume (in 10,000 heads)**

| | 1995 | 2000 | 2010 |
|---|---|---|---|
| Cow | 13,206 | 16,615.2 | 23,783.3 |
| Pig | 48,501 | 65,834 | 99,894.6 |
| Poultry | 336,606.2 | 470,435.4 | 843,575.8 |

*Sources: China's Commercialization Strategy Design for Bioenergy Technologies, by Zhang Zhengming, China Environment Press, 1999.*

### *C. Constraints to the Development of Animal Waste Methane Projects*

With extensive research and development, methane technologies now have improved fermentation efficiency and gas output, use better materials and equipment. The results have led to improved quality and lower costs.

The overall level of China's methane technology has nearly approached full commercialization. Problems remain, however, such as the large initial investment required, poor financial earnings and issues regarding standardized design and equipment specifications. Although the economic viability of these projects is still in doubt, improving the technology and manufacturing process should enhance technical and economic performance. Table 5.4 demonstrates how additional technology and expanding treatment can enhance the financial returns:

**Table 5.4: Economic Performance Analysis for Methane Projects (Hangzhou Fushan Methane Project)**

| | Excluded after treatment | Includes after treatment |
|---|---|---|
| Initial investment,Yuan | 771,500 | 821,500 |
| Annual operating costs,Yuan | 50,300 | 56,300 |
| Annual direct return rate ,Yuan | 65,700 | 130,200 |
| Benefits from avoidable environmental losses,Yuan | 81,900 | 81,900 |
| Project life, Yuan | 15 | 15 |
| Financial discount rate,%, | 10 | 10 |
| Financial net current value,Yuan | – 28,500 | 334,600 |
| ***Financial internal return rate,%*** | ***9.28*** | ***17.42*** |

** The second column: Solid residuals after the anaerobic digestion processing (biogas production) are treated to become higher-grade fertilizers and feedstock. This treatment can increase economic benefits of the whole system.*

*Data sources: "Economic Assessment Approach and Its Applications for Environmental Impacts of Poultry Farm Methane Project", Tsinghua University, 1995.*

Another barrier is the environmental pollution caused by large breeding farms. The chemical oxygen demand (COD) of large pig farms often exceeds the standard by 53 times; biochemical oxygen demand BOD exceeds that maximum level by 76 times, and suspended solids (SS) in water by 14 times. Although environmental protection agencies can and do levy fines when farms exceed standards, it is possible to develop a methane recovery project that does not have an additional adverse impact on the environment.

## Pricing For Methane Recovery Projects in China

Two projects demonstrate the pricing issue surrounding methane development. The market price of gas at the Shanghai Xinghuo Farm Methane Project is 1.20 Yuan per cubic meter, similar to the pricing of coal gas or natural gas. There was a large demand and revenues reached the point at which the internal return rate was 12%. Assuming the price goes down by 10%, its IRR will float between 11% and 15%, still a viable economic performance.

In another example, the Fushan Farm Methane Project runs its business as a public service by offering a price only at 0.25 Yuan per cubic meter. As a result, its IRR only reached 4.28%. It can be seen that pricing has a direct implication on the economic performance of methane projects. In certain areas of the country, the price for recovered methane gas can compete favorably with other resources and is a viable option. State-owned or subsidized enterprises that cannot sell gas at the market price, however, will be at a disadvantage.

*Financing:* Shortage of capital is another factor restricting large methane projects. In some cases, the budget for the methane recovery project can be larger than the cost of building the entire farm itself. This seriously hampers the potential for small to medium sized breeding farms.

The daily gas production volume of a large methane project will reach 1000-2000 $m^3$/day with a total engineering investment between Rmb 3–10 million Yuan. A medium methane project of 500-1000 $m^3$/day will have a total engineering investment between Rmb 800,000 to 3 million Yuan. At present, financing for methane projects comes mainly from bank loans, although the State Economy and Trade Commission (SETC), Ministry of Agriculture and local governments do contribute some subsidies. When assessing these projects, the bank uses an approach designed for ordinary industrial projects and does not take into account any social and environmental benefits.

*Investment Policies:* There is no investment policy in China that supports the development of methane projects. Discount loans dedicated to renewable energy projects are supposed to be available from SETC, but these policies have never really been implemented. The state has provided very limited preferential policies (eg: tax relief) for these kinds of projects. For example, methane projects can receive a discount in the VAT from 17 to 13 percent. This level is insufficient to jump-start the industry and is not nearly as low as the small-hydropower VAT rate of 6 percent. Other barriers include:

* The engineering design and construction of large methane projects follows no unified standards. There are no certification system or construction specifications. As a result, most enterprises are in a weak position when it comes to screening applications for project bids.

* The degree of automation needs to be further improved. Most of today's large and medium methane projects in the country operate manually or semi-manually. This can affect the operation of the methane project, causing leakage and possibly even explosions.

* Some key equipment is not quite up to the standards for commercialization. Examples include the separator of solids from liquid, desulferization devices and control systems.

* A well established technical support and service system is another important way in which a specific technology area is developed. Unlike the solar water heater industry, methane technologies have not yet developed their own technical service network, impeding the implementation of methane projects.

* There is a general lack of awareness among people who can best utilize this technology, and more information dissemination is needed. Unlike other renewable technologies, Western countries provide little economic and technical assistance in promoting organic waste treatment for breeding farms.

[i] *China Statistics Year Book 1999*. State Statistics Bureau, China Statistics Publishing House, September, 1999.

[ii] *Clean Water and Blue Skies: China's Environment in the New Century*. World Bank, September, 1997.

[iii] Mark Hertsgaard, "Our Real China Problem," *The Atlantic Monthly*, November, 1997. **Error! Bookmark not defined.**

[iv] *Statistical Review of World Energy*, 1999, BP Amoco. Also: "Coal and Natural Gas Competition in the APEC Economy." APEC, Bangkok, August, 1999.

[v] "Statistics of Rural Renewable Energy, 1998," Department of Scientific and Technological Education, Ministry of Agriculture.

[vi] *International Energy Outlook 1999*. Energy Information Agency, U.S. Department of Energy (DOE).

[vii] *Potential of Renewable Energy: White Paper of the State Laboratory*. DOE/EIA, March 1990.

[viii] *Energy Strategy of China Sustainable Development*. Chinese Academy of Engineering, December, 1998.

[ix] Essays from "Workshop on China Wind Energy Development in the 21st Century." Beijing, March 2000.

[x] Op. Cit. 4. Also, *World Energy Outlook, 1998*. U.S. Energy Information Agency.

[xi] Op. Cit. 8.

[xii] Information for small and mini hydropower from: *China Rural Energy Year Book of 1997, 1998 and 1999*. China Agricultural Publishing House.

[xiii] One study estimated that excluding illegal cutting, timber harvesting occurs at two to three times the rate of reforestation. It is estimated that the standing timber resource has dwindled from 64 million cubic meters in 1949 to 29 million cubic meters in 1980. That suggests an annual deforestation rate of 1.83 percent per year.

[xiv] Of the existing breeding farms, there are only 500 whose annual breeding volume has reached 500 head or more – 5 percent of the total; there are 2,000 pig farms with a breeding volume for 500 head or above – 20 percent of the total.

[xv] Zhang Zhengming, Deng Keyun, Ralph Overend. "Strategy Design for the Commercialization of China Biomass Energy Technology." China Environmental Science Publishing House, January, 1999.

## *Chapter 6: Geothermal and Tidal Electricity Generation*

### I. Geothermal

Around the world today, 21 nations generate 8,000 megawatts of electricity from geothermal resources. In addition, 11,300 thermal megawatts are used in more than 27 countries for direct use applications such as aquaculture, greenhouse operations and industrial processing. Geothermal energy sources are of growing importance in China and have large potential, for direct use in heating or cooling. China has a long history of geothermal utilization for direct applications. The country's geothermal resources are mainly medium- and low-temperature ones. While China does not have a large resource relative to other countries, much geothermal energy can still be tapped. The total exploitable high temperature (>150°C) geothermal resources in China are estimated at 6,744 MW, located mainly in Tibet and west Yunnan.[1]

*Most of China's best geothermal resources are in Tibet. One plant provides half of the electricity to Lhasa.*

Taking into account the resources, market demand, environmental protection, government policies and other factors, the installed capacities will be equal to 100 MW by 2010, and up to 500-1,000 MW by 2050.[2] Despite the potential, China today has only five operational geothermal facilities with a capacity of less than 28 MW:

* Yangbajan geothermal power plant (Tibet): 25.18 MW
* Naqu power plant (Tibet): 1.0 MW
* Langjiu power plant (Tibet): 1.0 MW
* Fengshun power plant (Guangdong): 0.3 MW
* Huitang power plant (Hunan): 0.3 MW.

The largest geothermal power plant, Yangbajin, with a capacity of 25.18 MW is near Lhasa, the capital of Tibet, and provides almost half the electricity for the city. The price of geothermal electricity from this plant – 0.64 yuan/kWh – is quite high but still not enough to cover the generation cost. The local administration subsidizes the plant's operation.

Only Yangbajin and Naqu stations utilize a high temperature resource ranging from 140 to 160° C. One of the best geothermal resources was found at one of the sites in the Yangbajain Field in Tibet, with a geothermal fluid temperature of 329.8° C at a depth of 2,007 meters. Other plants built around the country, however, suffer from a low water temperature and most are unable to run on a routine basis.

**Government Policy and Industry Development:**

China's geothermal resources are generally located far away from high-demand areas. If the government were to develop a system whereby electricity generated by geothermal systems could be sold through renewable energy credits or emissions credits, the economic benefits would be much more attractive. Under such a system, a utility in an area like Shanghai would purchase renewable credits (to fulfil some kind of mandatory requirement) without actually having the electricity transmitted to Shanghai (see more on credit trading in the policy section).

China must overcome several hurdles in developing its geothermal potential. As with other renewable technologies, geothermal development requires a degree of specialization currently lacking in China. The survey and assessment of resources need specialized equipment. Today, the country does not have a professional geothermal survey team, which hinders the ability to survey potential sites.

Finally, the drilling techniques applied to geothermal development are basically the ones derived from the oil industry. To adapt to the high-temperature working environment, developers need to make necessary changes to key oil drilling techniques such as mud drilling. The materials and equipment used have to be adapted to function in an environment of hard and broken rock stratum and corrosive fluids.

## II. Marine Energy Technologies[3]

With 32,000 kilometers of coastline and more than 6,500 offshore islands, China has a large potential for tidal and wave energy generation. In general, the marine energy potential is as follows:

* *Tidal Energy*: The exploitable tidal resources are 21.8 GW, with a possible annual electricity output of 62.4TWh. About 40 percent of this potential is located in Fujian with 47 percent located in Zhejiang.

* *Ocean Currents*: The potential from harnessing the energy from ocean currents is 14.0GW, of which one half is in Zhejiang.

* *Wave Energy*: The potential wave power resources are 12.9 GW, of which one third are in Taiwan.

* *Ocean Thermal Energy*: The exploitable ocean thermal energy is 1320-1480 GW. The Xisha Islands and the offshore areas east of Taiwan have the best conditions for this type of development.

**Progress to Date:** China has built seven small experimental tidal facilities, with a combined installed capacity of 6 megawatts. Zhejiang's Jiangxia Tidal Power Station has an installed capacity of 3.2 MW. Another larger tidal flood facility has an installed capacity of 5 MW. Two other wave-activated experimental facilities are in the process of construction, with a combined installed capacity of 200 kW. There is also one tidal current plant under construction, with an installed capacity of 70 kW.

China began studying wave power generation in the 1980s and established two shore-based experimental generation stations of 3 kW and 20 kW. During the Ninth Five-Year plan period, a larger 100 kW shore-based station was launched. In addition, using more recent technology that enables power to be generated with a lower level of swing motion, a "swing wave" station was constructed at Xiaomai Island, Qingdao. Another 50 kW swing wave facility is under development.

China has also successfully developed a "twisting column" wave power generation unit that will power navigation beacons on the South China Sea. More than 300 small beacon lights with wave-activated generators and three wave-activated experimental stations have been installed, with a total capacity of 40 kW.

In summary, after a decade of studies and experiments, China's wave power generation technologies have made remarkable improvement, especially with regard to turbine design, system control, monitoring and windstorm resistance. This progress has laid a solid foundation for the commercialization of wave power generation technologies. Many experts believe that after 2020, wave and tidal current power generation will become commercial. After 2030, ocean thermal power generation may become commercial as well.

# Part III:  Non-Electric Renewable Energy Technologies

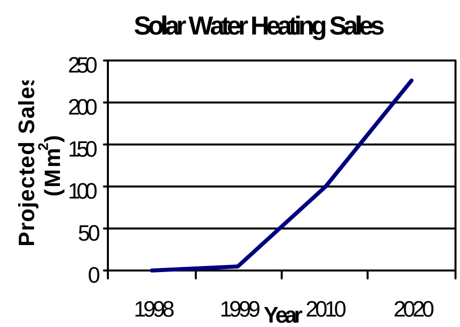
## *Chapter 7: Solar Water Heating*

In addition to the renewable technologies that provide electricity, many also provide heat and hot water and therefore play an invaluable role in displacing coal and biomass for everything from cooking to hot water.

Solar energy is perhaps the most widely used renewable resource in China, solely because of the popularity of solar water heating. At present, China ranks first in the world in the manufacture and use of solar water heaters.

### *I.  The Growing Industry*

In 1990-1998, the total heat collection area used for solar water heaters increased by ten times – from 1.5 million square meters ($Mm^2$) to 15.0$Mm^2$. The 1999 sales reached 5$Mm^2$, worth 3 billion yuan. In the next decade, solar power water heaters are likely to increase at an annual rate of 15 percent to reach 100$Mm^2$ by 2010, 200-250$Mm^2$ by 2020 and 400-600$Mm^2$ by 2050.




Today, about 1,000 enterprises are engaged in the development, manufacturing, marketing and installation of solar water heaters. The industry, with an annual growth rate of 20-30 percent, has today a yearly capacity of 6 million $m^2$,.  Solar water heaters are also being exported to countries in Southeast Asia and Europe. Characteristics of the industry include:

* More private manufacturers.  Among 188 enterprises investigated, only 44 are owned by the state.  Collectives or private companies own the rest.

* More enterprises are located in the east than in the west.  The solar water heater industry definitely has regional characteristics (see Table 7.1).

* Most are small companies.  In 1997, the Specialized Committee on Solar Energy surveyed 188 companies in the industry.  The vast majority of the solar water heater businesses – about 80 percent – were small enterprises.  Less than 20 percent were large with an annual capacity greater than 10,000 $m^2$.  Of those, only two companies exceeded 100,000$m^2$/year.

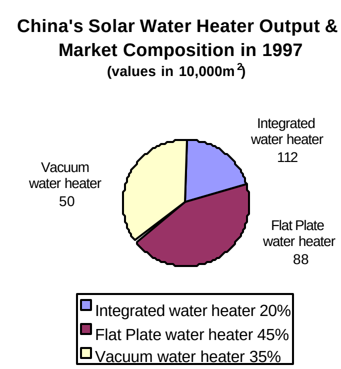
- **Table 7.1: Major Regional Distribution of Solar Water Heater Manufacturers in China (based on survey data collected in 1997)**

| Area | Number of Enterprises | Annual capacity >10,000 $m^2$ | Annual capacity > 5000 $m^2$ |
|---|---|---|---|
| China as a whole | 188 | 35 | 26 |
| Beijing | 15 | 5 | 2 |
| Tianjin | 2 | 1 | 1 |
| Hebei | 42 | 5 | 4 |
| Jiangsu | 31 | 10 | 4 |
| Anhui | 13 | 3 | 2 |
| Shandong | 25 | 5 | 3 |
| Guangdong | 7 | 2 | 1 |
| Sichuan | 3 | 1 | 1 |
| Yunnan | 16 | 2 | 7 |
| Gansu | 4 | 1 | 1 |
| Shanxi | 3 | 0 | 0 |
| Liaoning | 6 | 0 | 0 |
| Zhejiang | 4 | 0 | 0 |
| Henan | 9 | 0 | 0 |
| Guangxi | 1 | 0 | 0 |
| Hainan | 1 | 0 | 0 |
| Xinjiang | 2 | 0 | 0 |
| Shan'xi | 3 | 0 | 0 |
| Heilongjiang | 1 | 0 | 0 |

*Data sources: Survey Report on Solar Water Heater Manufacturers, 1997, by Chinese Specialized Committee on Solar Thermal Utilization.*

## *II. The Technologies*

At present there are three major types of solar water heaters available in the market: stuffy flat plate and storage (integrated) system, flat plate, and evacuated tube heaters. The output of solar water heaters and their contribution to the market are given in the table 7.2.




As far as the solar water heater market distribution is concerned, there is a strong regional correlation. Vacuum water heaters are found mostly over China's coastal areas such as Beijing, Tianjin, Shandong, Jiangsu and Guangdong. Plate or ensemble water heaters tend to be produced and sold in Hebei, Shanxi, Shan'xi, Gansu, Yunnan and Guangxi. The regional distribution of solar water heaters is not shaped by accident. Distribution of each type of water heater is closely related to economic development, technical aspects, energy supply, demand and solar energy resources in each region.

The core component of solar heating applications is the thermal collector. Starting in the 1950s with the development of solar heat collectors, China has conducted extensive studies on the optimal structures, shape, heat storage, and reflection characteristics of collectors. Chinese industry has developed thermal collectors of different specifications and applied technologies to meet specific needs. China has developed a 5 kW, high-temperature solar Sterling generation unit and designed solar stoves. Unfortunately the Sterling generation unit failed to meet its goals, but the solar stoves have become a proven technology and are now in mass production.

China has conducted studies of medium/high temperature thermal collectors with some ongoing work being done by the Institute of Electronic Engineering and Chinese Academy of Sciences. These institutions have developed parabolic trough collector and generate temperatures up to 250$^{o}$ C. This technology has found experimental applications in building material and timber processing industries. The lower temperature thermal collectors, however, have seen the fastest technical development and improvement.

- **Table 7.2: Technical and Economic Features of Chinese Made Solar Water Heaters**

| | Integrated | Flat Plate | Vacuum |
|---|---|---|---|
| Heat collecting area ($m^2$/unit) | 0.3-1.0 | 1.0-2.0 | 1.0-1.2 |
| Average system efficiency (percent) | 45-50 | About 45 | 40-45 |
| Hot water output (kg/day) | 60-70 | 70-100 | 70-100 |
| Water temperature (C) | 40-60 | 40-60 | 40-70 |
| Average price (Yuan /$m^2$) | <500 | 700-1000 | 1500-2500 |

*Date sources: "Draft of Rural Energy Development Study in the P.R.China", Asian Development Bank, 1996.*

*Solar water heating in China displaces 2 million tons of coal equivalent each year, creating benefits that continue to grow as the technology expands.*

*Integrated Water Heaters:* The integrated water heater is a combination of heat collector and water tank. The advantages of the integrated water heater are its simple structure, easy installation and lower costs. About 20 percent of Chinese-made solar water heaters fall into this category. Such water heaters are able to work from May to October in northern China and from March to November in the south. Annual average heat collected per square meter provides 70-100kgce (see Table 7.2).[4] Its weakness is the extensive nocturnal heat radiation. As a result, the heated water cannot be used overnight and it cannot work during the winter season in cold climates. This type of water heater is cheaper and therefore more attractive to lower income families. At present, the integrated heater's market niche is the rural area.

*The Flat Plate Water Heater:* The flat plate water heater has many designs – the copper-aluminum- plate water heater currently dominates the market. The water heater is composed of a flat plate heat collector and separate water tank operated on natural circulation. The flat plate heat collector is composed of the heat absorber, transparent hood, back and side heat insulating layer and frame. At present the total output volume of flat plate water heaters has exceeded 1.12 million $m^2$, about 45 percent of the total solar water heater production. The average efficiency of this type of water heater may reach 45 percent or above with an average heat loss low enough to exceed the national standard. Flat plate water heaters have the advantages of long life (10 to 15 years) and pressure resistance with daily hot water output per square meter reaching 70-100kg at 40-60 degrees.

*The Evacuated tube Water Heater:* The evacuated tube water heater has about 35 percent of the total market share in China. Evacuated tube water heaters are designed in mainly two types. One is the full glass evacuated tube water heater with a heat collector composed of dual layer coaxial glass tubes. The tubes are made of super hard Pyrex glass capable of producing high temperatures (250-280 degrees). The selected paint adheres strongly to the glass surface simplifying coating requirements. Such water heaters can be used all year in cold areas. They not only provide daily hot water and boiling water, but such water heaters can also provide thermal energy for technical processing, drying, wine brewing acceleration, air-conditioning and sea water desalination.

The other type of such water heater is the heat pipe heater. It is a high tech product that combines heat pipe and vacuum technologies. Some of its products have been exported abroad. Its major component is a heat pipe-based, vacuum heat collector with a heat loss coefficient around 1.7-2.2 $W/m^2\,^oC$, high temperature resistance (250 degrees max.), fine cold resistance (-250 degrees) and pressure resistance (0.5 Mpa). With a light collecting area of one square meter, these heaters can produce 170-200kg of hot water at 45-80 degrees in the summer. The high price limits the sales of this product.

## *III. The Economics of Solar Water Heating*

Analysis indicates that the construction of a modernized assembly line producing 4500$m^2$ (about 45,000 tubes) of evacuated tubewater heaters requires an investment of Rmb 12.3 million. If investors provided Rmb 2.5 million and a bank loaned the other Rmb 9.8 million, the financial internal return rate and economic internal return rate will be 16.01 percent and 29.26 percent respectively. This assumes a construction period of 2 years, loan interest of 12 percent, an average sales price of 1,600 Yuan/$m^2$, and a product life of 10 years. The payback for the investment would be 5.5 years. These figures demonstrate the economic viability of the industry and help explain its steady development.

An investigation was completed on a family of four in the Shanghai area with a full glass evacuated tube water heater, and the results are given in the table below.[5] These numbers indicate that the solar water heater is cleaner and safer than the gas water heater and using solar to heat water may save Rmb 393.0 Yuan/year for gas consumption.

- **Table 7.3: Economic Performance of Solar and Gas Water Heaters**

| | Solar water heater plus electric heating system used for backup | Gas water heater |
|---|---|---|
| Scale | $1.5 m^2$ | 10 liters |
| Initial investment | 3200 Yuan (including electric heater) | 1500 Yuan |
| Life span | 10-15 years | 5-10 years |
| Heating efficiency | 0.52 | 0.8 |
| Power tariff | 0.6 Yuan/kWh | - |
| Gas tariff | - | 1.2 Yuan/$m^3$ |
| Annual power consumption | 73kWh | - |
| Annual gas consumption | - | 364 $m^3$ |
| Cash interest | 2.25 percent | 2.25 percent |
| Equipment depreciation | 6.7 percent | 6.7 percent |
| A) Annual power expenses | 43.8 Yuan | - |
| B) Annual gas expenses | - | 436.8 Yuan |
| C) Annual depreciation | 214.40 Yuan | 100.5 Yuan |
| D) Annual interest | 80.00 Yuan | 37.5 Yuan |
| Annual total operation expenses (A+B+C+D) | ***338.20 Yuan (not including compound interest)*** | ***574.80 Yuan (not including compound interest)*** |

*Data sources: "Assessment of Economic Performance of Household Solar Water Heater," Solar Energy, by Liu Jianmin, 1999*

The next table illustrates the technical and economic features of a large solar water heating system.[6] The system was installed in 1995 and remains operational today. The system is a copper-aluminum plate heat collector with a collecting area of 200 $m^2$. It is displacing a coal-burning boiler (1 ton per hour) to supply hot water. The boiler is used when the solar system cannot fully meet the household needs.

- **Table 7.4: Basic Technical and Economic features of Large Household Solar Water Heater and Its Alternative Coal Burning Boiler**

| Solar water heater | Alternative coal burning boiler |
|---|---|
| Local solar radiation total: 585x $10^4$ KJ/$m^2$/year | Boiler capacity: 1.0 t/h |
| Solar energy utilization coefficient: 0.7 | Number of boiler: 1 unit |

| | |
|---|---|
| Water heater average conversion rate: 0.65 | Boiler efficiency: 0.4 |
| Initial investment: 135,200Yuan | Coal thermal value: 16720 kJ/kg |
| Of which heat collector: 68,000 Yuan | Coal price: 200Yuan/t |
| | Annual coal consumption: 50t |
| | Initial investment: 86,850 Yuan of which boiler:45,000Yuan |
| ***Annual system operation costs: 50 Yuan in first 5 years*** 150 Yuan in the second five years | ***Annual operational costs: 11,600 Yuan*** |

*Date sources: "Economic Performance Intercomparison of Large Solar Water Heating system", Solar Energy, by Henan Academy of Sciences, 1998.*

The advantages of the solar water heater include lower coal consumption and therefore operational costs. O&M costs for the traditional boiler, as well as coal delivery costs, are also dramatically reduced. Studies by the Institute of Energy at the Henan Academy of Sciences concluded that with a ten-year life span and a 10 percent internal discount rate, the financial net current value of a solar water heating system is Rmb 26,800 Yuan with an internal return rate as high as 27.9 percent. All of the evidence proves the strong economic viability of this renewable resource.

## *IV. Energy Displacement*

There is no question that solar water heating displaces electricity and fuels that would otherwise be used to heat water. Assessing the amount of pollution avoided can be estimated by looking at surveys of the methods used to heat water. One survey in five Chinese cities found that two thirds of residents used gas (LPG, natural gas or coal gas) to heat water. Ten percent used electricity, and 23 percent used coal.

Of the 15 million square meters of solar heat collecting area, about 8 $Mm^2$ is in rural areas. Extrapolating from the fuel data and the urban/rural ratio, the annual estimated fuel displacement is about 120 kgce per square meter of solar collection area. Multiplied by 15 million, the total comes to 1.8Mtce per year. If the number of solar water heaters increased by 15 percent per year (as is estimated), continuing environmental benefits will continue to accrue.

## *V. Special obstacles and problems*

Although solar water heaters enjoy the greatest market of any renewable technology, they still face many obstacles in production and sales:

* *Uneven product quality:* Most water heater products are manufactured in accordance with national standards, but with lax enforcement and many enterprises simply produce poor quality products. The most serious flaw in quality is the short life span. Heaters should last 10 to 15 years, although many Chinese products, particularly ones manufactured by small enterprises, last only 3-5 years – potentially giving a black eye to the entire industry.

* *Poor Service and Maintenance:* Many of the manufacturers pay little attention to after-sale service and have no system to service consumer problems. By contrast, the U.S. had 40 solar water heater manufacturers and 116 technical service firms in 1997. That 1:3 ratio is completely reversed in China and approaches 4:1. Consumers are rightfully concerned that there will be no place to turn if they have trouble with their systems. Many Chinese companies are small businesses with loose distribution networks and few quality guarantees. To expand the market, the industry needs to provide more technical support, perhaps through an expansion of their service business network.

# Chapter 8: Space Heating

## I. Passive Solar Design in Housing

In 1990-1998, the construction areas of passive solar houses increased from 0.4 million square meters ($Mm^2$) to 15.0$Mm^2$. China's passive solar houses have their own particular architectural styles. Its variety covers almost all the styles of civilian houses. The solar house can save 25 kgce of energy per square meter during the heating season. The initial outlay increases by 10-40 percent and the investment recovery period is 2.5-10.0 years.

Passive solar houses are seen mainly in the medium-sized and small cities and towns and in the rural areas in North China with winter heating requirements. In 1995, the new housing construction in North China towns and cities reached 2,020 $Mm^2$, of which 1,500 $Mm^2$ were heated by solid fuel burning stoves. The new housing construction in rural areas was estimated to be 800 $Mm^2$, making the total new housing area for both cities and rural areas 2300 $Mm^2$. The houses that use solid fuel stoves for heating are mainly bungalows and low buildings, suitable for passive solar design.

New housing construction is expected to reach 3,500 $Mm^2$ by 2010, 5,000 $Mm^2$ by 2020 and 8,000 $Mm^2$ by 2050. If 3 percent, 8 percent and 25 percent, respectively, used passive solar design, the total area of solar houses would reach 100, 270-400 and 1,000-2,000$Mm^2$. Using a figure of 30 kgce per square meter, the fuel use avoided would equal 3, 8.1-12 and 30-60 Mtce, respectively.

## II. Geothermal Space Heating and Other Direct Utilization

Although electricity generation is low, China has a long history and rich experience in using geothermal energy for heat. Hot springs have been used for space heating and for the treatment of disease since the Ming Dynasty. There are 1620 sites throughout China where geothermal energy is in direct use today. In 1998, the direct utilization volume of medium and lower temperature geothermal resources in China was 1,914 MWt, ranking first in the world, with an annual output of 4,717 GWh or about 0.4 Mtce.

The areas using geothermal water for planting purposes amount to 3,060 hectares, and areas using geothermal resources at animal breeding facilities total 1,735 ha. There are also 200 hot spring recuperative centers.

**Economic Potential:** ***The analysis below – from the Tianjin Xianda Geothermal Company – demonstrates the attractive economic paybacks from geothermal heat development***[7]

| | |
|---|---|
| Total heating area | 115,000 $m^2$ |
| Total heating load | 5790 kW |
| Heat for supply | 5757 kW |
| Initial Investment | Rmb 9.15 million |
| Of which geothermal well | Rmb 3.5 million |
| Construction period | 1 year |
| Life span | 15 years |
| Operational costs | Rmb 1.0381 million |
| Of which: heating<br>Hot water for daily life | Rmb 842,400 |
| Heat supply costs | Rmb 195,700 |
| Financial net current value: Before tax | Rmb 3.91 million |
| After tax | Rmb 1.59 million |
| Financial Internal Return Rate: Before tax | 14.58% |
| After tax | 10.83% |

*Data sources: the above sample was made on the heating supply system of Tianjin Xianda Geothermal Co. "Assessment of Renewable Energy Implications on Technology, Society, Resources and Environment and Related Policy Making Studies", Internal Report, by Zheng Zhengming et al.*

*The above analyses were based on the following assumptions: loan interest: 6 percent; loan repayment period: 8 years; geothermal resources fee: Rmb 0.5/ton; running water fee: Rmb 1.40/ton; power tariff: Rmb 0.50/kwh; salary and benefits: Rmb 800/person/month; heating fees collected: Rmb 18.50/$m^2$ during heating season; daily hot water fee: Rmb 5.0/ton*

### III. Biogas for Cooking and Lighting

Another major potential resource for cooking and lighting is biogas pits in rural areas. Today, 6 million farm households have biogas digesters that produce an estimated 2 billion cubic meters of methane gas. The gas generated by 200 large and medium-sized biogas projects using industrial organic wastewater is estimated to be 320 million $m^3$. The gas generated by 540 large and medium-sized biogas projects using animal and poultry waste amounts to 60 million $m^3$.

In the future, the demand for biomass energy will focus on new technologies, such as large and medium-sized biogas pits and gasification. It is expected that the country will produce 7 billion $m^3$ biogas by 2010, including 3 billion $m^3$ by large and medium-sized biogas projects, up to 10 billion $m^3$ by 2020 and 20 billion $m^3$ by 2050.

### IV. Other Rural Methane Uses

The methane recovery applications have broadened from cooking and lighting applications to urban wastewater treatment, aquaculture, and other applications. It has become an important force in creating more jobs for rural workers and improving the efficiency of agriculture. About 3.5 million farm households now produce methane for a variety of purposes, with some additional methane liquid to treat seeds, breed aquatic animals and grow mushrooms using methane. All of this demonstrates the strong prospects for the technology.

The technology for making alcohol for alternative fuel vehicles has already been commercialized in other countries. The annual output in Brazil is 12 billion liters, and the United States produces 4 billion liters. The minimum cost is about 12 cents/liter. China is developing a process for making alcohol by using sorghum stalks. The technology is expected to become commercial by 2010, when the annual alcohol output could reach 3 million liters by 2020 and 10Mt by 2050.

*Solar stoves are a particularly good alternative for areas where fuelwood is scarce, such as Gansu, Tibet and Hebei.*

## *Chapter 9: Alternative Cooking Methods*

### *I. Solar Stoves*

Solar stoves, which were developed in the early 1980s, now number 240,000, primarily in Gansu, Qinghai, Tibet, and Hebei. These areas are rich in solar energy and lack other energy resources, particularly wood. In Tibet, for example, herdsmen who once cooked with fuel wood had to turn to cattle dung when forest growth proved too slow to keep up with demand. In areas with dense populations, however, even dung became difficult to obtain. When the State Council implemented the "Sunlight Plan" promoting solar stoves in Tibet, it was well received. In 1998, solar stoves were used by 76,000 Tibetan households.

A typical Chinese solar stove boils 1 liter of water in good sunshine in 20 minutes. The area of the mirror is two square meters.

### *II. Biomass Cooking Stoves*

In 1998, the biomass that was used for direct burning – e.g. cooking – reached 202 Mtce. In recent years, China has made great achievements in the use of energy-efficient stoves. By the end of 1998, 184 million families had used such stoves, accounting for 77.7 percent of rural households. The heat efficiency of such stoves is more than double that of traditional stoves.

In recent years, the Nordic countries and Austria have also improved wood-burning stoves by compressing biomass fuel into shapes, with the heat efficiency reaching over 70 percent and emissions greatly reduced. China is using this experience to develop high-efficiency, low-pollution stoves. In the future, as more households become connected to the grid, biomass energy consumption in direct burning in either cook stoves or for space heating is likely to decline to 140 Mtce by 2010, 90 Mtce by 2020 and 40 Mtce by 2050.

## *III. Stalk Gasification*

China is a large agricultural country with a huge output of agricultural produce and stalk resources. In 1996, China's stalk output reached 705 million tons. Apart from those applied for animal feeds, fertilizers, industrial raw materials and household fuels, 107 million tons remain unutilized, a rich resource for stalk gasification. Experts predict China's stalk volume available for fuel in 2000 will be 150-160 million tons of coal equivalent.

Because of several barriers, however, the technology will remain in the experimental stage without state pricing, taxation and other economic policies. One problem is the diffuse distribution of the biomass waste resources creating costs associated with collection and delivery. The other is difficulty with storage. In the South, shelter from rain is a problem while in Northern China, fire is another. In addition to these issues, local governments – and possibly the central authorities – will need to address the following:

* Levels of carbon monoxide emissions exceed the standards, although there are no official standards for rural areas;

* Tar treatment and gas purification need to be improved;

* Reliability and security of biogas systems needs to be refined;

* A lack of national equipment specification and system performance standards. Shandong Province has proposed standards for quality control and construction, but nothing exists on the national level.

Economic Hurdles:

* *Large Initial System Investment:* stalk gasification technology has found its market mainly in rural areas. For a village of 200 households, it is difficult for the villagers to find the hundreds of thousands Yuan needed to construct a stalk gasification system. A recent sensitivity analysis indicated that an increase in the initial investment by 20 percent, will drop the IRR from 17.4 percent to 13.1 percent, indicating the heavy impact of initial investment costs on the overall economic performance of the project.[8]

* *Excessively low price for Biogas:* At present, the price for stalk gas is only 0.10 Yuan per cubic meter while the current cost of production is Rmb 0.22 Yuan per cubic meter. In order for a business to be

profitable, it would obviously have to be heavily subsidized. If one used liquefied petroleum gas having the same thermal value as the stalk gas, he can sell the gas at 0.23 Yuan per cubic meter and cover all costs. Only if the price of stalk gas increased would it become economically practical.

Finally, stalk gasification has important local environmental benefits. The Zhangdian District in Shandong provides a good example. As a result of the smoke coming from burning stalks, visibility on a local expressway was greatly reduced. The local government imposed a fine of 90,000 Yuan per hectare for burning stalks. Because processing the stalks into usable gas eliminates this problem, the fines helped accelerate the implementation of stalk gasification projects. This is an example of how a local environmental policy can provide a major incentive to invest in a new technology.

### Biomass and Low Income Households

The economics of renewable energy are determined mainly by the maturity of technology, fossil fuel prices and the internalization of environmental costs. At present, the heat derived from direct burning of biomass, household biogas pits and power generation by sugar cane slugs can compete with regular energy – particularly in rural areas. The prices of energy for rural daily life in Zhejiang province are: 200-300 Yuan/t for firewood, 140- 200 Yuan /t for crop stalks, 400 yuan/t for coal, 0.6-1.0 Yuan/$m^3$ for biogas and 0.3-0.5 Yuan/kWh for electricity. The kinds of energy and amount of consumption by residents are closely associated with their income levels.

**Table 9.1: Income Level of Rural Residents and Consumption of Energy in Daily Life (1997)**

| *Per household income, Yuan/yr* | *<1500* | *4500~6500* | *6500~9000* | *9000~14,000* | *>14,0000* |
|---|---|---|---|---|---|
| Energy for daily life, kgce/ yr | 807.0 | 1033.2 | 1350.9 | 1384.4 | 1645.4 |
| Of which, coal, kg | 876.1 | 999.0 | 1318.7 | 1556.3 | 1042.5 |
| LPG, kg | 21.6 | 28.7 | 68.5 | 71.2 | 103.3 |
| Oil products, kg | 12.1 | 18.4 | 35.8 | 180.0 | 229.5 |
| Electricity, kWh | 204.8 | 273.3 | 335.4 | 504.5 | 641.3 |

*Source: Energy Ministry of China/U.S. Department of Energy, Design for Market-oriented Development Strategy of Bioenergy Technologies in China, Project Expert Team, sample survey.*

# Part IV. Towards a Sustainable Energy Path: Policy Tools

## *Chapter 10: Renewable Energy Policies and Challenges*

### *I. Background*

While some renewable technologies, such as solar water heating and geothermal heating, have become competitive with conventional technologies, the same is not true for most renewable electricity options. Photovoltaic generation systems and small wind generation have proven to be cost effective for certain applications, but mostly in off-grid areas. Other technologies do not face a level playing field with mature fossil fuel technologies, which in most countries have enjoyed years of direct and indirect subsidies. With many renewable technologies, the scale of development has not been large enough to bring down the costs to a competitive level. For example, wind power – whose costs have come down remarkably in recent years – is still more expensive on a kWh basis than coal generation. However, if the wind industry received anything close to the level of government support that the state-owned coal mines have received, wind would certainly be competitive (and with no fuel costs, cheaper when analyzed on a life-cycle basis).

For these reasons, China and many other countries are looking at policy mechanisms that would give more support to renewable energy development, level the playing field and create an industry that can compete with the fossil fuels. Through policy mechanisms, the government can encourage the private sector to invest in renewable energy development. If correctly implemented, these policies would stimulate the commercialization of new technologies, expand the use of existing technologies, and ultimately reduce the costs of renewable energy. This section will examine the policies adopted by China and other countries, and offer a series of recommendations to improve the policy environment for renewable energy.

**Developing a Comprehensive Policy Framework:** Though each renewable technology may benefit from slightly different policies (mentioned at the end of each technology section), a comprehensive renewable energy policy framework that includes both long-term and short-term strategies is critical to the sustainable development of renewable resources in China. The importance of government leadership in setting a policy direction cannot be overestimated.

The electricity sector in China, as in most countries, has traditionally been a government monopoly. In China, the electricity industry was developed under the command and control of a centrally planned economy. Decades of tradition and experience have resulted in the corporate culture of electric utilities, in every country, being conservative by nature and partial to large central generation stations. China is no exception.

Most renewable resources are modular, with economies realized from the scale of their manufacture rather than from the size of individual facilities. Because they are different in scale, resource use and design from what utilities have traditionally built, renewables in most countries tend to be developed by independent power companies. As a result, to build a facility -- let alone interconnect with the utility and receive reasonable compensation for the generated power -- requires government encouragement. Government must also set up the rules under which such transactions can take place.

**Utility Restructuring:** The global restructuring of the electricity sector further complicates of renewable energy policies. During the transition to new electric industry structures, the role of the local utility becomes ambiguous. Concern about competition becomes the dominant theme while resource planning and oversight of various utility functions are suspended or at the least confused. The incumbent firm tries to consolidate its control over every aspect of energy production and distribution making it more difficult for new companies to enter the market. This is a critical time for a comprehensive policy framework to provide orderly guidance during the transition – particularly for new and emerging technologies. The following sections outline the phases of renewable energy development and lessons learned from other countries along with the current status of renewable energy policy in China.

## *II. Phases of Renewable Energy Development*

After more than twenty years of experience in both developed and developing countries, experts have observed that renewable energy tends to follow a consistent development pattern. There are some differences between electric generating technologies and non-generating technologies, between grid-connected and non-grid connected technologies, and between on-site and bulk power facilities. But there are many similarities as well. The following box outlines the typical renewable energy all phases.

## Typical Renewable Energy Developmental Phases

*Phase I. Research, Development and Demonstration of New Technologies*
* Resource Assessment
* Technology Development and Demonstration

*Phase II. Wholesale Market Development*
* Establishment of stable wholesale market rules and processes
* Establishment of companies willing and able to undertake resource development (usually IPPs)
* Establishment of manufacturing facilities
* Development of a financing framework

*Phase III. Cost Reduction*
* Project experience (multiple projects by individual companies)
* Increased manufacturing volume
* Development of related infrastructure and service companies to support the technology
* Standardized product

*Phase IV. Price Reduction*
* Assured volume/long-term opportunities
* Competitive market

*Phase V. Retail Market Development*
* Clear market rules
* Four or more individual companies
* Public education/information

All renewable energy technologies are not necessarily in the same developmental phase at the same time. For example in China, solar water heating is moving into Phase V while large wind generation for bulk power is in Phase II. Moreover, one technology may not have fully completed all the tasks in a phase before beginning tasks required for subsequent phases. Though such hopscotch behavior is quite common, leaving out critical tasks before jumping into later ones can lead to major failures in technology development. A common example is moving into competitive market situations (the price reduction phase) before conditions have been established to support cost reductions, such as a domestic manufacturing base for renewable technology. Such a move is not likely to lower prices and may actually discourage development. Similarly, trying to expand the retail market without first developing a standard product criteria can be self-defeating.

From the perspective of developing a strong policy framework, attention to these phases can help decision-makers identify areas where policy support may be needed and where lack of policy support may inhibit renewable energy investments. Finally, in virtually every country that has significant renewable energy facilities (excluding large hydro), that development has come from independent companies outside the electric utility itself. Though most countries and states have tried to encourage their utilities to build renewable energy facilities, with the exception of demonstration projects, the efforts have been generally unsuccessful.

## *III. Major Obstacles to Renewable Energy in China*

In general, renewable energy in China suffers from the lack of a well-articulated policy framework and an independent industry that can attract investment capital. Though they are making progress, most renewable technologies would benefit from a comprehensive set of policies, tailored to address each technology's phase of development. The following is a summary of some of the problems currently hampering the various renewable technology areas.

### *A. Grid-Connected Renewable Electricity Generation (Bulk Power)*

Grid-connected renewable generation in China suffers from the lack of a stable wholesale market coupled with no organized independent industry to develop the renewable resources. Though several wholesale market policies have been put forward by various state agencies (e.g. purchase of wind generated electricity, preferential loans and tax credits), they are uncoordinated and lack focus. They are difficult to implement and even more difficult to enforce. Lacking stable and enforceable policies makes it impossible to move to Phase III, Cost Reductions and then to Phase IV, Price Reductions. A more specific discussion of the barriers is summarized below:

* **Utility Barriers:** As a direct result of discussions about utility reform, the Chinese national utility is consolidating its influence and control over both the wholesale and retail markets. Signals from the national company indicate they are really not interested in being involved in renewable generating projects except through a subsidiary as a joint venture partner and then, only if there is enough profit. Local retail distribution companies also lack interest because, under the present system, local customers assume the entire burden of paying for the renewable projects. The uncertain future of China's utility reform adds additional confusion concerning future roles and market opportunities.

* **Lack of Enforceable Policies Encouraging Development of an Independent Power Industry:** In the United States, Congress passed the Public Utilities Regulatory Policy Act (PURPA) in 1978, which among others things required utilities to buy power at the avoided cost from independent power producers. This was the single most important law in the renewable energy industry because it created a

framework for enforceable power purchase agreements between utilities and IPPs.[9] Creating the IPP industry was crucial for renewable energy because utilities do not have the expertise or interest in renewable projects. It is critical for China also to develop an IPP industry. There are some legal provisions for the purchase of wind in China, but the policy is not enforced and utilities may still refuse to buy electricity from IPPs at a reasonable price. This has been the major problem with the World Bank-financed wind program in Inner Mongolia; utilities will only buy a small number of kWh at the IPP price formula, then only agree to buy the rest of the output at the average system price. In addition, the separate negotiation of power purchase agreements for each proposed generation project adds substantial transaction costs and additional uncertainties.

* **Pricing Policy:** Perhaps the most significant barrier is how electricity prices are set and costs distributed. Currently, utilities have to obtain approval from the central government to raise prices, but tariffs are set somewhat arbitrarily and do not necessarily correspond to the cost of production. Thus, a utility investing in wind may not be able to pass on the slightly higher costs to consumers (at a minimum, there would be a time-lag until the higher tariffs are approved). This means that any investment in premium power reduces cash flow. Compounding the problem is the fact that the costs for premium energy purchases are often not spread across the entire province let alone among provinces. Local distribution companies on the county or city level bear all of the costs for renewable power built within their jurisdiction, and that is a high burden. If the costs of renewable generation were spread across a larger group of consumers (all those who receive the benefits), their impact would hardly be felt.

* **Lack of Capital:** As is the case with other countries, those who offer financing need to have confidence in the economic viability of renewable energy projects. Without a stable framework in support of a real wholesale market, investors perceive renewable energy projects as high-risk. Although these projects are generally smaller than a conventional fossil fuel plant, it is much easier to get financing for projects that utilize more mature technologies. "Tied aid"[10] comes with its own set of problems related to sustainability and the development of local Chinese manufacturing.

* **Transmitting Renewables From Rural Areas Where the Resources are Located to Urban Areas with the Demand:** In China, much of the renewable resources are in regions with low energy demand, such as Inner Mongolia and Xinjiang. Because the need for electricity could be hundreds or thousands of miles away, there are serious questions about the ability of China's already shaky transmission system to handle the movement of all this electricity. Where transmission capacity is not sufficient, it will be impossible to

*Independent power producers have much more experience with renewable projects than utilities -- a strong policy encouraging IPPs will be critical for China.*

get renewable generation to the cities that need it (without some huge investment in transmission lines)[11]. In fact, some laws limit the amount of renewable electricity that can be supplied to the local grid because of concerns about the additional burden on the transmission system. Another issue is related to the utility structure: the State Power Corporation (SPC) has only minority ownership in the Inner Mongolia Transmission Grid and therefore is reluctant to enter into agreements to transmit power from Inner Mongolia to demand centers outside the region.

* **Lack of Local Manufacturing for Most Technologies:** China is trying to develop an indigenous industry for renewable technologies, and has succeeded in some non-electric technology areas. But despite a good deal of research and development, China's wind, biomass and geothermal industries are not nearly as developed as their Western counterparts, which means less experience in installing, maintaining and servicing renewable facilities. It also means few investors with knowledge of developing products, assembling business plans and designing financing packages, etc. In addition, local manufacturing of renewable technologies should contribute to significant cost reductions. Relying on imported equipment limits the types of transactions and the number of companies able to compete in the market.

### *B. On-Site, Grid Connected Renewable Generating Technologies*

There are few policies to encourage on-site, grid connected renewable generating technologies. Such a set of policies could be particularly important in encouraging efficient industrial systems (e.g. biomass cogeneration) that can reduce air pollution while using agricultural or industrial waste as fuel. These and other types of renewable distributed generation systems can also improve grid stability and reduce the costs of transmission upgrades. An integrated resource planning process can identify the location of distributed generation sites with positive transmission grid potential.

### *C. Non-Grid Connected Renewable Generating Technologies*

The non-grid connected renewable generating technologies suffer from many of the same problems as grid-connected systems – no coherent set of incentive policies that are relevant and viable even under electricity sector reforms. China has an aggressive and successful micro-hydro program that could serve as a model for other renewable technologies for mini-grid and rural electric development.

### *D. Non-Generating Renewable Energy Technologies*

The non-generating renewable technologies are environmentally very important in China because they either displace the use of electricity (predominately generated by coal) or displace the direct burning of solid fuel in the home or factory. China has a good R&D program for non-generating renewable energy technologies and a thriving market for solar water heaters.

The single greatest barrier to broader use of these technologies is the standardization and quality of these products. Lack of product standards and poor reliability have proven to be barriers even for the most commercial renewable technologies. Many manufacturers simply make inferior products, and consumers have little recourse. The resulting concerns about reliably make consumers wary of purchasing these products, even if the government is offering consumer subsidies.

*Renewable energy becomes much more competitive when examined on a life-cycle cost basis.*

All of these barriers stem in part from a lack of coordinated policy support for renewable energy that could dramatically change the market dynamics. Many of these barriers create uncertainty in the marketplace, which makes investors unwilling to put the capital forward to develop the industry. It should be noted, of course, that China is not alone in facing these problems. Most developed countries have also struggled with these issues and have designed solutions that have sometimes succeeded and other times failed.

### *E. Renewable Energy Cost Issues*

There is a lot of confusion about the cost of renewable energy technologies compared to those of conventional energy resources. The appropriate comparison is one based on life-cycle costs. The capital costs of renewables tend to be significantly higher than for most conventional fossil technologies while the variable costs are proportionately much less. Estimating the long-term cost of fossil-fueled generation requires an estimate of future fuel prices that are notoriously inaccurate.

To compare the cost of new renewables with new fossil plants also requires some assumptions concerning the types of pollution control measures that will be required on new fossil plants in the future. Then there is the issue of externalities. Air pollution is the most obvious externality associated with fossil fuel plants. Disposal of nuclear waste, uranium enrichment and plant decommissioning are direct costs of nuclear plants that are often left out of cost comparisons.

For China, which faces a serious water shortage, there is also the issue of cooling water usage. Both fossil and nuclear power plants use large quantities of water for steam production, coal washing and cooling.

Finally, renewable energy technology costs are going down over time as their markets expand and local manufacturing is instituted. At the same time, the cost of most other generating technologies is rising because of environmental compliance, fuel expenses and other technology issues. Unfortunately, “renewables are too expensive” has become a mantra that is seldom examined to determine its validity using life-cycle cost comparison between similar technology applications. Over the life of a generation facility, developers in the United States are realizing that new coal generation is competitive with new wind, in part because of pollution abatement technology.

## *Chapter 11: Renewable Energy Policies Adopted in Other Countries*

Energy policy mechanisms fall into four distinct categories: 1) legal and regulatory requirements; 2) economic incentives designed to stimulate various types of investments (these can be tax incentives or subsidies from other revenue sources); 3) fees that generate revenue for special purpose programs; and 4) market promotion mechanisms. Table 11.1 indicates a range of strategy options that fall under each of the four categories.

**Table 11.1: Renewable Energy Policy Mechanisms**

| *CATEGORY:* | *STRATEGY OPTIONS:* |
|---|---|
| LEGAL & REGULATORY: | Integrated Resource Planning<br>Transmission/Interconnection Rights and Requirements<br>Energy Tariffs (e.g. Buy-back rates, net metering)<br>Mandatory Purchases (e.g. Set asides/PURPA/Feed-in Laws/NFFO)<br>Pollution Laws<br>Resource Laws<br>Equipment/Housing Codes and Standards<br>Standard Offer Contracts<br>Licenses and Permits |
| ECONOMIC INCENTIVES: | Low-interest Loans and Loan Guarantees<br>Investment and Production Tax Credits (Individuals/Corporations)<br>Resource Credits (e.g. Depletion Allowances)<br>Price Discounts and Customer Rebates<br>Tax Reductions (e.g. VAT, Import Tariffs)<br>Streamlined Financing Process<br>Other Subsidies (e.g. fuel enrichment/disposal, transportation) |

| | |
|---|---|
| SPECIAL REVENUE SOURCES: | Pollution Taxes<br>Wires Fees (e.g. System Benefits Charge/NFFO)<br>Emissions Credit Trading |
| MARKET PROMOTION: | Research Development & Demonstration<br>Resource Assessment<br>Competitive Bidding<br>Mandatory Purchases (e.g. Feed-in Laws, RPS and NFFO)<br>Green Marketing<br>Certification, Testing and Labeling<br>Public Education and Information<br>Government Purchases |

Many of these policies have been created because of the restructuring of the electricity sector. Under an increasingly competitive environment for power, government authorities have looked at many of these policies as a way to ensure that renewable energy and energy efficiency projects do not simply disappear.

Following is a more detailed description of some of the more popular renewable policy mechanisms being implemented today in Europe and the U.S.

**I. Mandatory Purchases with Set Percentages (e.g. Renewable Portfolio Standard and Renewable Set Aside):** Under this strategy, electricity suppliers must purchase or generate a set percentage of their electricity from renewable sources. A renewable energy set-aside was sometimes used under traditional monopoly utility structures. The amount of the set-aside could be determined through an Integrated Resource Planning analysis or a more ad hoc method. Many of the RPS programs have been developed in anticipation of electric utility reform. For example, Italian utilities have to reach two percent by 2002 (5 billion kWh in total). The Netherlands currently has a voluntary system for utilities to reach a three percent target by 2000, although the Government has indicated it may begin to impose fines on those utilities that fail to comply. Denmark is aiming to reach a target of 25 percent of total electricity consumption by 2010.

Ten U.S. states have now adopted the RPS, though experience with their operation remains limited. The rulemaking experience in Maine and Texas does indicate, however, that the RPS will encourage the least-cost renewable resources and ensure competition between renewable generators. When designed appropriately, the RPS can create a large and vibrant market for renewable energy. By giving the utilities flexibility in fulfilling their requirement, the resulting competition results in a more market-based approach than has been tried in the past.

***Renewable Energy Certificates (REC):*** If suppliers do not meet their quota of renewable electricity in other ways, they can purchase renewable energy certificates that may be sold in a secondary market. European utilities are now developing pilot projects to identify the issues regarding REC trading. The Netherlands has developed a renewable energy certificate program called the Green Label. One label is the equivalent to 10,000 kWh of renewable energy and can be sold to the highest-bidder (suppliers that exceed the three percent target can sell their excess green labels in the marketplace). Since renewable resources are often located in more remote or rural areas, tradable RECs can provide market pull for renewable energy in locations far from the demand centers. Credits can even be sold separately from the electricity eliminating some types of transmission constraints.

**II. Mandatory Purchases with Set Prices (e.g. Feed-in Laws, PURPA):** Under this system, renewable energy developers are guaranteed they can sell their power at a specified sales price (the feed-in tariff or avoided cost), coupled with a purchase obligation by electric utilities. Standardized interconnection requirements for renewable generators are also important of these types of purchases. The level and the duration of the price can vary, but the price level should be high enough and the duration of the sales contract long enough to ensure a market for renewable electricity. The guaranteed power sales price may also be amended periodically by regulators to reflect falling renewable energy costs or other market conditions. A number of past feed-in laws in Europe set the feed-in price as a percentage of retail electricity prices. These policies did not originally reduce the tariff when renewable energy costs declined, although current proposals do. The Public Utility Regulatory Policies Act (PURPA) in the U.S. was another type of mandatory purchase with a price set at the utility's wholesale avoided cost.

**Installed Wind Capacity for Selected Countries -- 1999 (Megawatts)**

| | |
|---|---|
| Germany | 4072 |
| United States | 2502 |
| Denmark | 1733 |
| Spain | 1722 |
| India | 1077 |
| Britain | 534 |
| Netherlands | 428 |
| China | 286 |
| Italy | 249 |
| Sweden | 216 |

*Source: American Wind Energy*

Since 1990, the German electricity feed-in law has required that wind power, solar, hydropower, and biomass receive 90% of the residential retail price of electricity (from 9.5 cents/kWh in 1991 to 8.8 cents/kWh in 1999). Though PURPA and the Feed-in Laws have frequently been protested by electric utilities, they have successfully launched the most diverse renewable energy markets in California and a sizable wind power market worldwide. Germany now represents one of the largest solar and wind markets. A sizable wind and solar manufacturing base has also developed there.

The major drawback to feed-in tariffs is that the guaranteed price eliminates the incentive to reduce costs. As the discussion of the U.K. system will show, introduction of competition can play a significant role in one of the primary goals of these policies – bringing down the cost of renewable electricity.

**III. Open Tenders and Reverse Auctions:** In the United Kingdom, the government issued competitive bids for a certain level of renewable capacity. There were five orders adding up to 1,500 MW of renewable capacity. The program's competitive design was very successful in bringing down the cost of the bids for projects, although actual implementation of projects has been somewhat slow. Despite the drawbacks, the Non-Fossil Fuel Obligation (NFFO) is generally seen as a model for other countries.

Competitive pressures do tend to favor larger companies, which can outbid smaller firms; the big established players have most experience and know how to reduce costs. As a result, most NFFO projects have been built by large companies from other European countries, such as Denmark, and no domestic renewable energy industry has developed in the U.K. This is an issue important to China. The open tender also tends to favor well-established, lower-cost *technologies*, although the U.K. Ministry of Energy tried to get around this by soliciting bids in different technology bands (see below). As table 8.2 shows, the submitted bids for various technologies decreased by as much as 75 percent over several years – between the first order (NFFO 1) and the last (NFFO 5) – demonstrating the effect of competition on price. Although some bids were too low and projects were not built, in general, competition successfully brought down the cost of renewable generation.

**Table 11.2: Examples from U.K.'s (NFFO) Price Reduction**

| | NFFO1 | NFFO2 | NFFO3 | NFFO4 | NFFO5 |
|---|---|---|---|---|---|
| Technology Band | Cost-justification | Strike Price (p/kWh) | Average Price (p/kWh) | Average Price (p/kWh) | Average Price (p/kWh) |
| Wind | 10 | 11 | 4.43 | 3.56 | 2.88 |
| Wind sub-band | - | - | 5.29 | 4.57 | 4.18 |
| Hydro | 7.5 | 6 | 4.46 | 4.25 | 4.08 |
| Landfill Gas | 6.4 | 5.7 | 3.76 | 3.01 | 2.73 |
| M&IW (mass burn) | 6 | 6.55 | 3.89 | - | - |
| M&IW (fluidized bed) | - | - | - | 2.75 | 2.43 |
| Sewage Gas | 6 | 5.9 | - | - | - |
| EC&A&FW (gasification) | - | - | 8.65 | 5.51 | - |
| EC&A&FW (residual) | - | 5.9 | 5.07 | - | - |
| EC&A&FW | | | | | |
| (AD) | 6 | - | - | - | - |
| M&I W with CHP | - | - | - | 3.23 | 2.63 |
| TOTAL | 7 | 7.2 | 4.35 | 3.46 | 2.71 |

*M&IW = Municipal and Industrial Waste*
*EC&A&FW = Energy Crops and Agricultural and Forestry Waste*
*AD = Anaerobic Digestion*
*Source: Adapted from "Renewable in the U.K." Paper by Dr. C Mitchell, Oct, 1998.*

Reverse auctions are another type of competitive process in which the developer bids for the subsidy required above what would otherwise be paid for conventional electricity. The bidder requiring the lowest subsidy wins the auction. This method is being used in California to distribute subsidies to developers of new renewable energy facilities. For example, if the average price for electricity is $.04/kWh and one renewable generator can sell power for $.06/kWh, the developer requires a $.02/kWh subsidy for the facility to be competitive. Another generator may only need $.01/kWh to be able to sell electricity into the market. In this case, the second project will receive the subsidy, encouraging other generators to seek as low a subsidy as possible. This model – bidding lower instead of higher – is why the concept is called a reverse auction. The concept is also used in Argentina as a method of choosing the Concessionaires who will supply power in Argentina's rural areas. These competitive auctions can help to bring down renewable energy prices once an industry has been sufficiently established that it has the experience to reduce costs.

**IV. Special Revenue Sources (e.g. System Benefits Charge/Pollution Tax):** Under a wires fee type strategy, each consumer pays a small amount (perhaps three to ten percent) as a surcharge on their electricity bill to support special programs like renewables. The UK NFFO program is supported by a fossil fuel charge, which pays down the higher kWh cost of renewable electricity. Switzerland and Italy have adopted such program as well as 14 U.S states. In California, the System Benefits Charge (SBC), as it is called, is between 0.3 and 0.45 cents/kWh, which amounts to three percent extra charged on a consumer's bill. That money will support $540 million worth of renewable energy programs and $872 million worth of energy efficiency programs per year in California until 2002. The main benefit of the SBC is that it is flexible and can be used to support a range of activities (subsidized loans, grants for new domestic manufacturing, customer rebates, R&D, etc.). Qinghai province has introduced a similar policy, but it is difficult to apply it nationwide because of political sensitivity associated with another tax.

*Competitive bidding in the U.K. brought the cost of renewable projects down by as much as 75 percent.*

In the U.K. the fee on fossil-fueled generation covered the incremental cost of nuclear and renewables. In other European countries, a carbon tax is used to fund renewable purchases. These types of fees can be used for a variety of purposes. They help to internalize externalities and when the fee is spread widely, can disperse incremental program costs to an exceedingly low level. In China, a local distribution company bears all of the higher cost of renewable power. At the other extreme is an SBC where the costs are spread across every consumer in the country – this brings the cost to each individual consumer to an imperceptible level.

**V. Economic Incentives (e.g. tax credits/reductions, low-interest loans):** The most common financing incentives are: tax credits or reductions on individual and corporate income taxes; reductions or exemption from certain energy taxes; price discounts and rebates; low-interest loans and loan guarantees. Economic incentives can be easily tailored to specific needs. For example, if the goal is to attract more investment capital, investment tax credits can be very effective. While production tax credits, based upon the energy output of a project rather than the capital input, can result in improvements in generating plant efficiency.[12] Cash rebates paid to consumers who purchase a specific product (e.g. a solar water heating system or renewable electricity) is a strategy for reducing the price differences of new renewable products in immature markets.

In the U.S., there is a national 1.5 cent/kWh production tax credit for power generated by wind and certain types of biomass (eg: an investor in a wind project can reduce their taxable income by an amount of 1.5 cents for every kWh generated). The EU is working on a model program to provide a simple way to administer low-interest loans. There is also a national proposal for a low-interest loan program for new renewable generation that would be funded by U.S. insurance companies (as a climate change mitigation measure).

Renewable energy technology and industries that have a history of investment tax credits often have a difficult time when such preferential policies end. For example, after investment tax relief was ended for the U.S. solar water heater industry, production dropped from 1,746,000$m^2$ in 1980 to 1,026,000$m^2$ and 200 manufacturers went out of business.

Theoretically tax relief does not require large outlays, only a willingness to forgo revenues. The limited size of the renewable energy industry in China should not have significant impacts on government budgets.

**VI. Special Tariff (Net Metering):** Net metering is a special tariff that is particularly popular now as a mechanism to encourage on-site, small scale, grid-connected renewable generators. This law requires the utility to either buy back (at the average retail rate) excess renewable energy from consumers who install on-site generating technology or at least deduct the kWh generated from the customer's total electricity bill. This policy is in effect in 28 U.S. states and is under consideration in several European countries. It reduces the cost of small on-site renewable generation like PV systems and can provide utilities peak power at average prices.

| TYPE OF POLICY | COUNTRIES WHERE POLICY IS PROPOSED OR ADOPTED |
|---|---|
| 1. Minimal Renewable Purchase Requirement (RPS or Set-asides) | Denmark, Italy, Netherlands, Japan,* India,* Portugal,* UK, 10 U.S. States |
| 2. Mandatory purchase and price | Germany, California, Spain, Denmark |
| 3. Open Tenders | United Kingdom, several U.S. States |
| 4. Special Fees | U.K., California, Switzerland, Italy |
| 5. Economic Incentives | Germany, Italy, U.S. – national/state level |
| 6. Net Metering | Italy, 28 U.S. States |

***** *Has been proposed in these countries.*

# *Chapter 12: China's Current Policies on Renewable Energy*

The Government of China has made a substantial effort to develop renewable energy. Many of these regulations, however, are published as general statements on the benefits of renewable energy and provide no legal changes that appreciably affect renewable energy development. For there to be major changes, regulations must not only be plans approved by governmental agencies but laws that have full review and ratification by the State Council and/or the National People's Congress.

## I. China's Current Renewable Energy Policies

The primary energy policies published by the Central Government are as follows:[13]

### *A. People's Republic of China (PRC) Law on Electricity*

This is China's first law on energy. The first chapter, "General Principles," states that the state encourages and supports renewable energy and clean energy based power generation. Chapter , "Power Construction and Consumption in Rural Areas", also stresses the importance of renewable energy.

In the 9th five-year plan for China's national economic and social development, the energy development strategy was defined as "centered around the coal based electric power with enhanced survey and development of petroleum and natural gas resources." The policy also stressed the necessity for developing small hydro power, wind energy, solar energy, geothermal energy and bioenergy.

### *B. Energy Efficiency*

The 1998 PRC Law on Energy Conservation described the important strategic role and position of energy efficiency and renewable energy in bringing about emission reductions and environmental improvement.

*C. Wind Power*

One of the most concrete laws was the 1994 Regulation for Grid-connected Wind Power Generation Management. This document stipulates that wind power shall be allowed access to the nearby grid and that the network shall purchase all output. The wind power tariff shall be determined based on the cost (both principal and interest repayment) plus a reasonable profit. The incremental cost of wind power above the average electricity tariff is also supposed to be shared by the whole grid. Although this policy seems direct and clear, utilities have either been able to get around this regulation, and the policy has not lead to significantly greater wind development.

There are two key differences between this law and the similar PURPA regulation in the United States. PURPA requires utilities to purchase all electricity from independent power producers – not just wind. In addition, the U.S. law, approved by Congress and signed by the President, is well enforced. China's regulations are more akin to plans approved by governmental agencies – they are not enforceable without the review and ratification by the State Council or the National People's Congress.

*D. Finances*

In 1999, the State Council, SDPC and the Ministry of Science and Technology issued the "Circular on Further Supporting the Development of Renewable Energy." The statement stressed that renewable power projects would enjoy priority for state bank loans. The National Development Bank is the lead institution providing such loans and would encourage the involvement of other commercial banks. The SDPC is to assist the developer to acquire bank loans for projects above 3MW. These types of loans have an interest-rate reduction of two percent below the commercial rate, a discount subsidized by the national or local government.

*E. Small Hydropower*

The fast growth of China's small hydropower industry resulted from direct Chinese Government support. In the earlier development stage, the Chinese Government adopted a series of policies benefiting the construction and development of small hydro generation. For example, small dams can be owned by private businesses, which can receive subsidies from the government. The discounted value added tax is another benefit.

### F. *Direct Economic Incentives*

* *Customs Tariff Relief:* With the gradual opening of Chinese markets, customs duties have dropped for many imports. And duties for renewable energy equipment are lower than the average. For example, imported wind turbines have no customs duty. Ironically, this hurts the overall objective of promoting local manufacturing because components of wind turbines have a three-percent customs tax. This policy provides an incentive to import complete turbine units from abroad and not to use as much local equipment as possible. Since local equipment is cheaper, the overall effect is to raise unnecessarily the cost of wind generation equipment.

* *Value Added Tax Relief:* At present, most renewable energy products are taxed at the full value added tax (VAT) level. The two exceptions are the VAT on biogas at 3 percent (the unified current VAT is 17%) and the one on small hydropower generation at 6 percent.

* *Income Tax Relief:* China's income tax system has greatly improved in recent years. At present the standard income tax paid by enterprises is 33 percent. Local authorities collect income tax from local enterprises, and some regions, such as Inner Mongolia and Xinjiang, have developed preferential policies to support the development of renewable energy (Table 8.3).

* *Discount price:* Local authorities have some measures for pricing of certain renewable energy applications. For example, Shanghai authorities have defined a higher price for biogass based cooking gas at Rmb 1.20 Yuan/$m^3$ while other provinces such as Sichuan and Guandong have offered discount prices for the cement used in biogass tank construction.

* *Discount loans:* The Chinese Government created discount loans dedicated to rural energy development in 1987. These loans support biogas projects, solar thermal applications and wind power generation technology. In 1996 the fund totaled Rmb 130 million. The government offered a 50 percent discount on regular commercial bank loan interest. In addition, the government has made a limited number of low interest loans available for small hydro projects.

* *Subsidies:* The Central Authorities' subsidies in renewable energy are mainly offered for research, development as well as some local subsidies for solar energy and wind power.

In the U.S. and Western Europe, subsidies are collected from system benefits and fossil fuel taxes. In China, subsidies come mainly from the government general budget. Because China has limited financial revenues and the demand for subsidies comes from so many sectors of the economy, the dependence on public funds is not a long-lasting strategy. To be effective, subsidies have to be well designed. Who should be subsidized and with what type of mechanism are key design issues. Direct subsidies to users may not reach the target objective. When investors are subsidized together with open tendering and fair competition, the dual objectives of production expansion and cost reduction can be achieved. Three key targets of subsidies include:

- Subsidies paid to investors. The Chinese government's investment in the construction of local small hydropower stations is an example case. The U.S. government provided 15% investment subsidies for wind power investors, although the policy has since expired. Investment subsidies can be used to mobilize investors and increase production capacity.

- Output subsidies, such as the U.S. Production Tax Credit, are paid on the basis of production volume. At the present time, there is no such policy in China. These policies can have a dramatic effect on increasing output, reducing costs and improving economic benefits.

- Consumers' subsidies, a widely applied incentive in China. In addition to its extensive application in extending solar energy equipment and mini wind generators, these subsidies are widely used for efficient firewood stove and other bioenergy technologies. The objective is to spur the expansion of production capacity and thus reach the goal of cost reduction.

**Table 12.1: Incentives for Wind / Solar Energy Development**

| | **Inner Mongolia** |
|---|---|
| Current Status | 14.5 MW of large wind power generators, 18.5 MW of small wind power generation; household photovoltaic (PV) systems dominated by 10 –20Wp. |
| Subsidy policies | Rmb 25 million to users in 1986-90; Rmb 200 for each 100W wind power generator purchased or each 16W PV unit from financial budget. Annual subsidies of Rmb 300,000 for R&D activities; Working capital provided by local authorities for establishment of extension station in 56 counties. |
| Taxation policies | 3% VAT surtax on wind power generation; income tax relief for 2 years; 10.69-14.43 Yuan for VAT surtax on PV units of 16Wp –21.6Wp. |

| | |
|---|---|
| Pricing policies | Tariff calculated on repayment of principal and interest. 713Yuan/MWh including VAT in 1995 and 609 Yuan/MWh not including VAT; the difference is shared by grid and subscribers with 200 Yuan/MWh by grid and rest by subscribers in the form of subsidies 2.5 Yuan/kWh. |
| Loan policies | Rmb 400 million for wind power by State Economic and Trade Commission; Danish Government loans for wind power generation. |
| Other | Land use policies: Land tax collected on the land actually occupied;5 year income tax holiday for occupying arable land;10 year land tax holiday for occupying the unused land. |
| | **Xinjiang** |
| Current Status | 16.7MW of large wind power generation; 8000 household PV systems dominated by 10-20Wp. |
| Subsidy policies | 50-200 Yuan for PV unit and small wind power generation unit purchased; 1 million Yuan for R&D; Working capital for extension stations; 300 Yuan subsidies for PV users. |
| Taxation policies | 2 year tax holidays, 3 year tax relief and 5 year 15% income tax for foreign invested or joint venture with an operational life for 10 years. VAT holiday for products export. Monthly collected VAT and surtax at 17% and 10% respectively. Seasonal collected income tax at 15-33%; Import tariff and VAT at 12% and 17% respectively, with duty free for international donation. |
| Pricing policies | Tariff calculated on repayment of principal and interest. 698 Yuan/ MWh including VAT in 1995. The regular grid tariff is 118 Yuan/MWh in the area; The difference is shared by grid and subscribers. The added 2 cents/kWh with 0.5 cent for difference with rest borne by grid. |
| | **Gansu** |
| Current Status | 5000 household PV units mainly of 20Wp |
| Subsidy Policies | 300 Yuan for each PV unit purchased; Subsidies for R&D; Support for extension station |
| Taxation policies | Policies similar to that of Xinjiang in taxation on PV system with only exception for monthly collected value added tax on non-donated PV system. |
| Loan policies | Guarantee by local government for household PV system to secure a loan with interest rate at 3%. The subsidies came from additional tariff by 3 Yuan/MWh and 20% interest subsidized from financial budget. |
| | **Qinghai** |
| Current | 15000 household village PV station of 23 kW |

| | |
|---|---|
| Status | |
| Subsidy policies | 300 Yuan for each PV unit purchased; Rmb 500,000 for R&D; Working capital for extension stations |
| Pricing policies | Addition tariff 2 Yuan/MWh, with some of the revenues used to finance installation PV system |
| | **Northeast Grid** |
| Current Status | 6 MW of wind generation |
| Taxation policies | 6% VAT on wind generation. No tax relief for high power tariff (900Yuan/MWh) in Henshan, Liaonin. 6% for Donggang, Liaonin (100Yuan/MWh). |
| Pricing policies | Tariff calculated on repayment of principal and interest |
| Loan policies | Discount loans for wind power |
| Other | Land use fee paid on the area actually occupied by wind power generation with preferential treatment as foreign invested businesses |
| | **Gaungdong** |
| Current Status | 11.7MW of wind power generation |
| Taxation policies | VAT collected at 20 Yuan/MWh and 15% for income tax |
| Pricing policies | Tariff calculated on repayment of principal and interest; Grid tariff 770Yuan/MWh with difference shared by subscribers |
| | **Zhejiang** |
| Current Status | 1MW of wind power generation |
| Pricing policies | Tariff calculated on repayment of principal and interest; |

*Data sources: Draft Final Report on Financial Policies Promoting China's Renewable Energy Development by World Bank and China.*

*Research, Development and Demonstration Funds:* Funding from the central authorities for research, development and demonstration have gone for the following purposes:

Providing administrative expenses and research budgets for scientific research institutions.

- Supporting major scientific studies and related training: As shown by incomplete statistics, the total budget used in the 9th five-year plan period for this purpose exceeded Rmb 100 million.

- Offering project subsidies: In the early 1990s, for example, the Central Authorities invested Rmb 7 million in constructing 4 PV stations in Tibet as a demonstration project.

- Providing assistance in the planning process: In 1996, for example, the State Planning Commission, State Science and Technology Commission and State Economic Commission jointly published "Development Outlines for China's Energy and Renewable Energy Development in 1996-2010."

Despite this R&D support, the fact is that China remains for behind other countries in its renewable energy development. In the 1970s, other countries launched a large number of R&D programs, national labs and research projects for renewable energy. The National Renewable Energy Laboratory (NREL) in the United States is a prime example. Comparatively, China provided less investment in renewable energy studies with less than Rmb 100 million budget allocated for related national programs for the whole 9th five year plan period.

*G. Other Local Policies*

At present, about 10 provincial authorities such as those in Hebei and Shandong, have ratified laws related to renewable energy. These laws and regulations were shaped on the basis of existing problems and actual needs in the course of rural energy project construction and new energy development. These documents have played an effective promotion role in spurring renewable energy development in these areas.

As an example of local policy, the Shanghai municipal government allocated a financial appropriation of Rmb 10 million for a fund dedicated to the promotion of biogas projects using a market mechanism based on demand growth. Some local authorities such as those in Liaoning and Dalian provide a Rmb 700 subsidy for farmers who used methane to heat a greenhouse or nursery. This is in addition to low-interest loans of up to Rmb 2,000 for each system.

## II. China's legislative system and law making procedures

On March 9, 2000, the National People's Congress adopted the Legislation Law, which tries to establish a clear process for the passing of laws. The National People's Congress (NPC) and its Standing Committee formulate laws concerning state sovereignty, the criminal code, civil affairs, judicial affairs and the economy. The State Council is authorized to make administrative regulations; local people's congresses and their standing committees formulate local regulations other than those mentioned above.

In the absence of the national law or administrative regulations, local regulations may be made according to actual needs. Once the corresponding national laws are made, the local laws and regulations that come into conflict with the national laws will become invalid. In cases when the conditions for making laws are not ripe but there is an urgent need for some kind of regulation, the State Council is authorized to formulate administrative decrees, which will become law when appropriate.

## III. China's Technical Progress and Environmental Policy

China has mature technology for small hydropower, home biogas pits, solar water heaters, small windmill generators and medium and low temperature geothermal power. The technologies for wind power, PV, and large and medium-sized biogas pits are close to full commercialization. But the government needs to adopt incentive policies to promote their development. In the future, technical progress combined with small policies will bring down the costs. Wind power, for example, will likely fall to 0.32 yuan/kWh (about 4 U.S. cents/kWh) by 2010. The cost of photovoltaic cell power generation is likely to drop to 0.50 yuan/kWh by 2020.

*As emissions controls on coal plants inevitably become more stringent, the cost differential between renewables and coal will decrease.*

On the other hand, the cost of power generated by coal will increase. If environmental externalities are taken into account, the cost of coal power will rise sharply. And evidence in China suggests the government is becoming more serious about compliance with air pollution laws. In March 2000, the penalty fees on excessive $SO_2$ discharge were raised from 200 yuan/ton to 1,200 yuan/t. Although this has started only in Beijing, the law will be adopted in other cities and eventually throughout the entire country. The sharp rise of $SO_2$ discharge fees will weaken the competitive edge of coal and enhance the competitiveness of renewable energy. Some experts estimate that wind power and PV generation will be able to compete with coal power by 2010 and 2020, respectively.

**IV. China's Anti-Poverty Program and Renewable Energy:** Over the past 20 years, China has made major strides in eliminating absolute poverty. The impoverished population in the rural areas was reduced from 250 million in 1978 to 34 million by the end of 1999. In 1994, the Chinese government began to launch an anti-poverty program with the aim of lifting the 80 million people from poverty in seven years. This program has played an important role in promoting the power generation by using renewable energy.

In May 1994, the former Ministry of Power Industry launched a project to promote rural electrification, one of the government's key anti-poverty strategies. Initially, the initiative worked to provide electricity for drainage and irrigation in remote farming communities. By the end of 1998, , more than 60 million people had power for the first time. Power reached 99.2 percent of the townships, 98.1 percent of the villages and 96.87% of the rural households. The per capita electricity consumption in the rural areas rose from 36kWh in 1978 to 265kWh in 1998.

## V. Policy Implications and Recommendations for China

Any renewable policy should have a specified set of goals. These might include: (1) expansion of domestic manufacturing to bring about reductions in the unit cost of renewable energy equipment; and (2) reductions in the wholesale price of renewable generation. At a minimum, policy-makers should seek a more level playing field for renewables and an assurance of a stable wholesale market.

Next is the question of how to achieve these goals – what policy mechanisms need to be put in place to move toward the desired outcome. Designing the right policy mechanisms is vital and needs to be carefully considered. While this paper cannot fully design the mechanisms, we can offer some general recommendations. Perhaps the most important point to consider is that a combination of policies – not simply one or two – are needed to create a framework that addresses the variety of barriers and issues facing renewables in various applications.

## VI. Overall Goals

### *A. Cost Reductions*

Only with a reduction in the cost of renewable energy facilities and products will the market flourish. There are a three important ways to make this happen.

* *Increased Manufacturing Volume:* An increase in manufacturing volume for renewable technologies will result in a substantial cost reduction. The level of the cost reduction varies with the type of technology (e.g. PV panels may have the greatest cost sensitivity to increases in manufacturing volume). Increased volume of equipment production results from increased market demand. The most effective policies that increase market demand are market-mandated policies (e.g. PURPA, RPS, Feed-In Laws, Set-asides that come from the planning process). If properly designed and enforced these policies guarantee the demand for these technologies that will generate the economies-of-scale in manufacturing needed to bring down costs.

* *Development of Domestic Manufacturing Capabilities:* Switching from importing equipment to domestic manufacturing can also reduce costs – assuming that domestically produced equipment is of equal or superior quality. For large generating equipment, this requires careful policy planning that allows for the steady increase of component manufacturing (and the gradual decrease of imported technology) as local expertise is developed. Most technology transfer plans include a combination of the following: gradual shifts in import tariffs; incentives for joint ventures; development of equipment standards and testing program; and standardized criteria for competitive solicitations.

* *Experience in Building Multiple Projects:* The first project always costs more because the developer is learning about the resource, project design and implementation details. To achieve this learning experience requires two primary elements: (1) a robust market; and (2) an industry willing and able to undertake the construction of multiple projects. International experience has shown that development of an independent power industry (IPPs) is the key

to having the infrastructure support necessary to deliver grid-connected bulk power renewable energy generation.

### *B. Price Reductions*

Once cost reduction capability has been developed, price reductions can take place. These come primarily through competitive mechanisms like competitive bidding, reverse auctions, and renewable energy credit trading.

The other issue is reducing the relative price differences between renewables and conventional technologies. This can be accomplished by looking at externalities through integrated resource planning, environmental dispatch, pollution control regulations and/or pollution taxes. The recent six-fold increase in sulfur dioxide discharge penalties is a true example of these rising external costs. In some cases, wind power can be competitive in the long run because there are no fuel costs, which can fluctuate widely.

## VII. Recommendations

### *A. Development of an IPP Industry and an Active Wholesale Market for Their Power*

Because renewable resources are best developed by independent power producers, a consistent set of policies (both short and long-term strategies) implemented in an effective and timely manner, will form the foundation of an IPP and renewable energy industry. Again, China may want to look at the experience of the U.S. Public Utility Regulatory Policies Act (PURPA), which required utilities to purchase the power generated by IPPs (including cogeneration and renewable energy) at avoidable costs. The policy created conditions for fair competition between renewable energy based power generation technologies and those that are fossil fuel based. PURPA is a major reason behind internationally acknowledged U.S. achievements in wind and solar energy and its advanced position in bioenergy power generation.

If China were able to develop such a law – and make it enforceable through real legislative “teeth”, it could be the single most important contribution to renewable energy development in the country. The first step would be to 1) establish a fair purchase price for electricity generated from renewable resources (e.g. based on long-term marginal cost of power for the region); 2) expand the purchase requirement that currently exists for wind to all renewable generating sources; 3) assure transmission access for all renewable generators with any T/D charges the same as what the utility charges itself; and 4) develop a standard offer contract (with standards contract terms and conditions) that can be used as the default contract for all IPP power sales to a utility.

The advantage of market mandates is that they can kick-start the industry resulting in rapid increases in operating systems and cost reductions. In the wholesale electricity market this can be accomplished through PURPA or Feed-in type laws or renewable set-asides. In competitive retail markets this can be done through RPS or Feed-in type laws. It would be helpful to develop a market mandate process in the wholesale monopoly market that can be easily applied to the reformed retail market later.

### *B. Create a Strong Governmental Department to Exercise Unified Management*

The development and utilization of renewable energy in China today involves many departments and industries, whose responsibilities often overlap. There is no definitive answer as to which government agency is responsible for renewable energy development, and as with all bureaucracies, internal conflict is commonplace. To be effective and avoid duplication requires a strong central authority exercising unified management and coordination. Such an effort should be led by a Vice-Premier, similar to the Executive Meeting of the Energy Conservation Office at the State Council.

The advantages of this strategy are obvious – reducing confusion and strengthening the ability to enforce renewable energy and energy efficiency policies. Of course some overlap and duplication will always occur because the electricity sector covers many aspects of society and thus requires attention from more than one government agency. Therefore, coordination and collaborative program management will still be necessary.

### *C. Codify Laws and Strengthen Legislation*

Many of China's renewable energy regulations are only plans approved by governmental agencies for implementation – without the review and ratification by the State Council or National People's Congress. These regulations are similar to non-binding resolutions or statements of political support. If policies are to be implemented and enforced, they have to be approved by the State Council and depending on the type of regulation, the National People's Congress as well.

Government agencies that want faster adoption of renewable energy programs need to approach the Council and NPC and obtain their approval (which is not always easy). With that authority, however, agencies such as SDPC can develop detailed implementation plans with effective enforcement mechanisms. Without that authority, agencies can only push for more policy statements that can provide general guidance to lower levels of government but that may not lead to concrete action. SDPC should seek approval for very specific policies and then design the detailed plans that can then be passed down to and provide direction for the provincial development planning commissions. SDPC could start with implementation rules for the renewable energy regulations in force today. One example is the requirement of utilities to purchase wind-generated electricity, a rule that is not currently followed or enforced.

It is important to note how the Chinese legislative system is different from most Western systems. In China, proposed laws go from the executive branch (government agencies and the State Council) to the legislative branch (the National People's Congress). In contrast, the U.S. system has laws progress from the legislature to the executive branch. It should also be noted that just because a law is passed by the State Council does not mean it will automatically pass the NPC – many laws have been rejected in the past. Many renewable energy policies, such as those related to taxation, would only require State Council approval. Laws requiring greater structural changes, such as a Renewable Portfolio Standard, would require NPC approval as well.

### D. Transmission/Interconnection Policies

Regardless of the type of generation used, China's electricity system would benefit from improvements to its transmission and distribution network. Present weaknesses in the system reinforce the tendency to construct power generation plants near major population areas. This in turn magnifies the air pollution problems already present in urban areas due to motor vehicles, emissions from heating and cooking fuels, and industrial processes. Development of an interconnected national electricity grid would facilitate the construction of more distributed generation sources and the purchase of power from rural areas. The result would be improved efficiency of resource use and lower air pollution in cities.

In the design and expansion of China's transmission/distribution system, care should be taken to include transmission support for renewable resource development in more remote provinces. Moreover, the rules and guidelines for transmission access and use need to be technology neutral. The access rules should enhance the ability of intermittent and small generating resources to transmit power into the system as well as co-generators and self-generators.

Open access for all generators to transmission and distribution services at a fair price (e.g. the same as the utility charges itself) is a fundamental requirement for the establishment of an independent power industry.

### E. Incentive Policies/Supporting a Domestic Renewable Energy Industry

It would be most beneficial for China to have a consistent set of policies to stimulate a wholesale grid-based renewable electricity market. This set of policies would include: carefully crafted tax policies (that stimulate both investment and efficient energy production); loan guarantees or other mechanisms that reduce the perceived risk of financing renewable energy projects; guaranteed transmission access and fair transmission rules; good resource assessment and fair resource laws. A simple example is to extend the 6 percent VAT that now applies to small hydro facilities to all other renewable resources as well.

To the extent that foreign expertise and equipment is needed, carefully designed joint venture arrangements – some of which are already on-going – should be expanded. It is important that import tariff structures encourage joint ventures using imported equipment early in the process while supporting a gradual move to domestic production of component parts. At the present time, a higher import tariff is paid on components than on whole generating systems. As a result, this discourages the development of local manufacturing capability.

If economic incentives are used, they should be tied to the performances of enterprises (eg: a subsidy provided on a per-kWh basis). All types of economic incentives should be time limited through sunset clauses; otherwise the industry will have no incentive to become self-sufficient.

A recent report by Tsinghua University illustrates the potential cost reductions of smart incentive policies. Listed below are some examples for wind generation:

* *Income Tax:* If the current income tax rate of 33 percent were reduced to 15 percent and 0, the cost of wind generation per kWh would be reduced by 4.3 percent and 8 percent respectively.

* *VAT:* If the current 17 percent value added tax on *electricity sales* were reduced to 6 percent and 0, the cost of wind generation would decrease by 9.6 percent and 14.6 percent respectively (this incentive is tied to generation because the exemption only comes when a kWh is sold);

* *VAT II:* If the current 17 percent VAT on *wind-generation equipment sold to developers* were reduced to 6 percent and 0, the cost of wind power would decline by 8 percent and 12.4 percent respectively.

* *Low-Interest Loans:* If the interest rate of a long-term loan were reduced from 15 percent to 7 percent, the overall cost of wind power would be reduced by 21.7 percent.

### *F. Adjust Pricing Policies*

A general principle of any sustainable renewable energy policy is that the project developer, through a contract with the utility, should be able to recover their project costs. The Chinese government could make it easier for utilities to pass the costs of renewable generation to a broad range of consumers by streamlining the tariff approval process and specifying a reasonable price formula. In addition, Government could help by making clear to whom these costs will be disbursed. An important corollary is that the overall burden of renewable energy should be spread across all the citizens who benefit from the project (both from the energy as well as the environmental benefits -- perhaps over the entire provincial grid). This way, the incremental cost to consumers would be fair and very low. Changing these policies is within the power of the government today. These options are compatible with the present electricity sector and do not require a large amount of institutional change or implementation effort.

Another way the incremental costs of renewable resources can be paid is by using some type of national wires fee (e.g 1%/kWh) that is charged on every kWh bought or sold. The revenue from this fee is then used to pay the incremental cost of renewables above that of conventional power. This strategy could result in a virtually imperceptible increase in electricity rates (since it could be spread over all customers, not just at the regional level) and such a system is fully compatible with reformed electricity markets. The disadvantage is that a wires fee requires additional administration and institutional change that adds transactions costs. In addition, with a national fee already charged to electricity consumers to pay for the Three Gorges Dam Project, there is a good deal of public sensitivity to levying another tax.

### *G. Carry out Additional Resources Assessment and Increase R&D*

There is an urgent need to carry out detailed assessments of wind, biomass, geothermal and solar energy resources and fix the total resources volume, technically exploitable volume, and economically exploitable volume. This will provide a reliable basis for policy and project planning and design. The Chinese government's investment in renewable energy R&D and its proportion in the science and technology expenses are on the low side and should be adjusted upwards.

### *H. Credit or Certificate System*

To promote economic development and construction of renewable facilities in western regions, a mandated market allowing for renewable energy credits or certificates to be sold separately from the energy could encourage sales to regions with large load centers and bypass some of the transmission problems. In other words, the utility in Shanghai could pay for the premium on renewable energy in Inner Mongolia without actually getting the renewable electrons. The reason to do this would be to meet the requirements of a mandated market (eg: an RPS). The renewable electricity would be fed into the local grid far away but the credit would go to the Shanghai utility. The advantage of this strategy is that it could be implemented in the wholesale market first (starting with some voluntary provincial pilots) where there are fewer players and transactions are easier to track. This would allow some experience with certificate trading to see how such a program could be modified for use on a broader scale later as electricity sector reforms are implemented.

### *I. The Government Can Take the Lead in Demonstrating Green Power Procurement*

At the beginning of the entry into the market of renewable energy, the government should take the lead in demonstrating renewable energy applications. In addition, government facilities can incorporate renewable energy facilities of all types (including biomass fueled cogeneration) at appropriate sites. This type of leading through example plays an important role in stimulating greater renewable energy use. Examples include using non-grid connected renewable energy generation to provide core services in remote areas such as potable water, health facilities, schools and community meeting centers. The government can also use PV systems to power emergency telecommunications facilities and roadside signs. City and county governments can use landfill gas and sewage gas from garbage and waste disposal to power government buildings.

The advantages are huge in terms of visibility (eg: the government demonstrating it is a good "global citizen"). In addition, the government can achieve economies-of-scale by bundling the energy needs for human services facilities into one economic and technical package. Moreover, the incremental cost of expanding these energy facilities to serve the local community is much lower than trying to finance and build each energy facility separately.

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[5] "Statistics of Rural Renewable Energy, 1998," Department of Scientific and Technological Education, Ministry of Agriculture.
[6] *International Energy Outlook 1999*. Energy Information Administration, U.S. Department of Energy (DOE).

[7] *Potential of Renewable Energy: White Paper of the State Laboratory*. DOE/EIA, March 1990.
[8] *Energy Strategy of China Sustainable Development*. Chinese Academy of Engineering, December, 1998.
[9] Essays from "Workshop on China Wind Energy Development in the 21st Century." Beijing, March 2000.
[10] Op. Cit. 4. Also, *World Energy Outlook, 1998*. U.S. Energy Information Agency.
[11] Op. Cit. 8.
[12] Information for small and mini hydropower from: *China Rural Energy Year Book of 1997, 1998 and 1999*. China Agricultural Publishing House.
[13] One study estimated that excluding illegal cutting, timber harvesting occurs at two to three times the rate of reforestation. It is estimated that the standing timber resource has dwindled from 64 million cubic meters in 1949 to 29 million cubic meters in 1980. That suggests an annual deforestation rate of 1.83 percent per year.
[14] Of the existing breeding farms, there are only 500 whose annual breeding volume has reached 500 head or more – 5 percent of the total; there are 2,000 pig farms with a breeding volume for 500 head or above – 20 percent of the total.
[15] Zhang Zhengming, Deng Keyun, Ralph Overend. "Strategy Design for the Commercialization of China Biomass Energy Technology." China Environmental Science Publishing House, January, 1999.
[16] *China Annual Energy Review 1997*. Department of Resource Conservation and Comprehensive Utilization, SETC.
[17] Op. Cit. 8.
[18] Information for Marine Energy Section from *China Annual Energy Review 1997*. Department of Resource Conservation and Comprehensive Utilization, SETC.
[19] *Rural Energy Development Study for China* (draft). Asian Development Bank, 1999.
[20] Liu Jianmin. "Economic Evaluation of Household Solar Water Heaters," Solar Energy, 1999.
[21] *Study on the Survey and Forecast of China's Coal Consumption*. SDPC and MOCI Joint Survey Team, 1999.
[22] Zhang Zhengming, "Impact Evaluation of Renewable Energy Technology on Society, Resources, and the Environment," November, 1999.
[23] Zhang Zhengming, "Commercialization Strategies for Biomass Technologies in China," China Environmental Publishing House, 1999.
[24] Similar laws were also passed in the UK, Germany, Spain and Denmark.
[25] Low-interest or no interest loans from other countries tied to the purchase of generating equipment from that country.
[26] On the other hand, improved reliability, efficiency and system diversity would support significant investments in transmission grid improvements.
[27] The subsidy is only granted when the facility sells a kilowatt-hour, so the generator wants the plant to work as well as possible to squeeze out every unit of electricity.
[28] Economic Incentives Policy Study for China Renewable Energy Development, edited by Zhao Jiarong,China Environmental Science Publishing House, October,1998.

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## APPENDIX A: POLICIES, LAWS AND REGULATIONS ASSOCIATED WITH RENEWABLE ENERGY

### *I. China's Laws and regulations Associated With Renewable Energy*

| **Name** | **Highlights** |
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| 1. Amendments to the Constitution | Repositioning the non-public sectors of the economy, establishing the position of the non-public sectors of the economy as an important component part of the socialist market economy. This is of major significance in promoting the development of renewable energy because domestic and foreign experience shows that private investment is key to the rapid development of renewable energy. |
| 2. Energy conservation law (promulgated on Nov. 1, 1997 and implemented on January 1, 1998) | Article 11: The State Council and provincial governments shall take out energy conservation funds from funds for capital construction and technical transformation for use to support the rational utilization of energy and the development of new and renewable energy.<br><br>Article 37: The designing and construction of structures shall adopt energy-efficient structures, materials, appliances and products to raise heat insulation performance and reduce consumption in heating, refrigerating and lighting.<br><br>Article 39: Governments at all levels shall strengthen rural energy construction, develop and utilize such new and renewable energies as biogas, solar energy, wind energy, water energy and geothermal resources according to the principle of proceeding from the actual local conditions, mutual supplementation among different forms of energy, comprehensive utilization and practical results. |
| 3. Power Law (promulgated on December 28, 1995 and effective on April 1, 1996) | Article 5: The state encourages and supports the use of renewable energy and clean energy to generate electricity.<br>Article 22: When power production enterprises with independent legal person status demand the on-stream of power, power-handling enterprises shall accept.<br>Article 37: Power going on stream shall be the same price in the same power grid, of the same quality.<br>Article 47: The state shall grant preferential policies to rural electrification. |

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| 4. Agricultural law (promulgated and effective on July 2, 1983) | Article 54: In developing agriculture, it is necessary to use resources rationally and protect the ecological environment. The people's governments at all levels shall work out agricultural division into districts, agricultural environmental protection plans and rural energy development programs and organize to control agricultural ecological environment. |
| 5. Construction law (Promulgated on Nov. 1, 1997 and effective on March 1, 1998) | Article 4: The state supports construction sciences research to improve the designing level and encourage energy conservation and environmental protection, advocate for the use of advanced technologies, equipment and processes, new building materials and modern management methods. |
| 6. Forest law (promulgated and effective on Sept. 2, 1984) | Article 4: Forest includes firewood that is mainly used for producing fuel.<br>Article 6: Limit quotas shall be imposed on tree felling and tree planting and afforestation and sealing off the mountains for cultivating forests shall be encouraged.<br>Article 19: Felling of trees is banned in fine woodland and special purpose forests.<br>Article 22: Publicly owned or collectively owned wasteland and hills suitable for afforestation can be contracted to collectives or individuals for afforestation. |
| 7. Land management law (Promulgated on June 5, 1986, amended on Dec. 29, 1988 and revised on Aug. 29, 1998) | Chapter Two Ownership and Use Right<br>Chapter Four Protection of arable land<br>Chapter Five Land for construction purposes. Land acquisition shall be compensated for according to purpose of use, including land compensation fees, resettlement fees and fees for compensating for attachments and green crops on the land.<br><br>The compensation fees for arable land shall be 6-10 times the average annual output value of the previous three years. The standard of compensation for the resettlement of each agricultural person is 4-6 times the average annual output value in the preceding three years. The compensation fees for per mu of arable acquisitioned shall not exceed 15 times the average annual output value in the preceding three years. |
| 8. Water law (promulgated and effective on Jan. 21, 1988) | Article 16 Development and utilization of waterpower resources are encouraged. The ecological environment shall be protected, also taking into account the needs of flood prevention, water supply, irrigation, navigation and fisheries in building hydropower stations. |

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| 9. Company law (promulgated on Dec. 29, 1993 and effective on July 1, 1994 and revised on Dec. 25, 1999.) | It standardizes the organization and behavior of companies. In 1999, the revised version adds this article: Initiators of high and new technology companies limited may use industrial property right and non-patented technologies as their share of investment; the state supports high and new technology companies to enter the securities market for direct financing. |
| 10. Township enterprise law, (promulgated on Oct. 29, 1996 and effective on Jan. 1, 1997) | Article 19 Township enterprises in minority nationality areas, remote regions and poor areas and those need special support as provided by the state industrial polic ies shall enjoy tax concessions.<br>Article 29 Township enterprises shall rationally develop and use natural resources according to law.<br>Article 35 Township enterprises shall develop pollution-free or less polluting and low resources consuming production. |
| 11. Securities law (promulgated on Dec. 29, 1998 and effective on July 1, 1999) | It standardizes the behavior in the issue and trading of securities. The approval system is changed into verification system for the listing of enterprises, that is, the listing of enterprises shall be verified according to the capital funds and profits, thus opening the way for non-governmental enterprises to be listed on the stock market. |
| 12. Contract law (Promulgated on March 15, 1999 and effective on Oct. 1, 1999) | Chapter Ten Contract on the supply of electricity, water, gas and heat<br>Chapter Sixteen Construction contract<br>Chapter Eighteen Technology contract |
| 13. Price law (Promulgated on Dec. 29, 1997 and effective on May 1, 1998) | It provides the pricing behavior for managers and the government; the general level of prices shall be subject to control and prices shall be subject to supervision and examination.<br><br>Article 23 Public hearing system shall be introduced in the pricing by the government of public utilities and merchandise of natural monopoly. |
| 14. Law against unfair competition (Promulgated on Sept. 2, 1993 and effective on Dec. 1, 1993) | It encourages and protects fair competition, checks unfair competition to protect the rights and interests of managers and consumers. |
| 15. Product quality law (Promulgated on Feb. 22, 1993 and effective on Sept. 1, 1993) | It provides for the responsibilities and obligations of producers and sellers concerning product quality and the supervision and management of product quality. |

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| 16. Air pollution prevention and control law (Promulgated on Sept. 5, 1987 and revised on Aug. 29, 1995) | Article 15 Enterprises shall give priority to the use of clean production technological processes that are energy efficient and discharge less pollutants to reduce air pollution<br><br>Article 24 Coal washing and processing, the lowering of sulfur and ash contents shall be promoted and mining of coal with high sulfur and ash contents shall be limited.<br><br>Article 27 Areas where acid rain has already or is likely to occur or other sulfur oxide pollution is serious shall be demarcated as acid rain or sulfur oxide control zones.<br><br>Article 28 It is encouraged and supported to produce and use lead-free gasoline and limit the production and use of leaded gasoline. |
| 17. Water pollution prevention and control law (promulgated on May 11, 1984 and revised on May 15, 1996) | It provides the formulation of water environment quality standards and standards for discharging pollutants, the supervision and management of water pollution prevention and control and the prevention of ground and underground water from being polluted. It is associated with hydropower projects, the utilization of geothermal resources and the treatment of animal and poultry drops and urban sewage water and the hot wastewater discharged by thermal power plants. |
| 18. Water and soil conservation law (Promulgated for implementation on June 29, 1991) | Article 13 Governments at all levels shall organize agricultural collective economic organizations and state forestry and livestock breeding farms to plant firewood forests.<br><br>Article 19 In building railways, roads, water projects, opening mines and power enterprises in mountainous, hilly and wind and sand zones, the environment impact report shall have the water and soil conservation plans with the consent of the departments in charge of water administration. |
| 19. Law on the prevention and control of solid pollutants (promulgated on Oct.30, 1995 and effective on Jan. 1, 1996) | Article 4 The State encourages and supports clean production and the full recycling and rational utilization of solid wastes.<br>Article 30 Enterprises shall rationally chose and utilize raw materials, energy and other resources and adopt advanced production processes and equipment to reduce the generation of solid wastes.<br>Article 37 Urban garbage shall be cleared timely and efforts shall be made to rationally utilize it and render it harmless. |

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| 20. Law on the prevention and control of environmental noise pollution (Promulgated on Oct. 29, 1996 and effective on March 1, 1997) | Article 13 For construction projects that might produce noises, there must be environment impact report and control measures. |
| 21. Law of marine Environmental protection (promulgated on Dec. 25 1999 and effective on April 1, 2000) | Chapter Six Prevention and Control of Marine Environment Pollution Caused by Marine Engineering Projects |
| 22. Science and technology progress law (promulgated on July 2, 1993 and effective on Oct. 1, 1993) | Article 25 Preferential policies shall be granted to enterprises and research organizations that engage in the development and production of new and high-tech products in and out of the new and high-tech development zones.<br><br>Article 46 Enterprises shall be encouraged to increase investment in R&D and the R&D fees shall be entered into cost account.<br>Article 47 State-owned financial institutions shall support commercialization of research achievements by providing loans. |
| 23. Decisions of the CPC Central Committee and the State Council on strengthening technical creation and developing high technology and realization of industrialization (Promulgated on Aug. 21, 1999 and effective on Nov. 2, 1999; Ministry of Finance and State Taxation administration issued circular for implementation) | * The R&D funds provided by units or individuals to research organizations that are not sponsored by enterprises and institutes of higher learning shall be deducted in full from the taxable income of the year.<br>* Income from technology transfer, technology development and associated technical services and consultancy shall be free from business tax.<br>* The VAT for software products of software developers and producers shall be 6% and the wage expenditure may be deducted before paying income tax.<br>* The zero tax rate shall be introduced for export of new and high technology products.<br>* Tariff and VAT in the import link shall be exempt for enterprises for importing equipment for their own use in the production of products listed in the state high and new technology products catalogue and importing technology and accessories and replacements together with equipment according to contract and for the payment for software fees abroad for importing the technologies mentioned above.<br>* Personal income tax shall be exempt on bonuses in equity to individual for applying research achievements by research institutions and institutes of higher learning. |

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| 24 Regulations on stimulating the conversion of research achievements approved for circulation by the General Office of the State Council (March 30, 1999) | * The proportion between new and high technology as production factor and distribution shall be raised from 20% as provided in the company law to 35%.<br><br>* The shares of bonuses for people who have made major contributions to the R&D and conversion of research achievements shall not be lower than 50% of the total awards. |
| 25. The State Council set up creation funds for science and technology-oriented medium-sized and small enterprises (Feb. 1999) | It is a specially earmarked government fund, totaling one billion yuan. The ways of support includes free assistance, discount loan, capital input; targets include energy efficiency and new energy. 1000 projects were approved in 1999, totaling 820 million Yuan and 460 million have already issued. Local matching funds were 850 million and bank loans were 3.75 billion Yuan . |
| 26. Decisions on problems concerning environmental protection by State Council (issued in Aug. 1996) | * To exercise control over total volume of pollutants discharged and introduced the administrative leader assuming the sole responsibility for the environment quality.<br>* To resolutely control new polluting sources;<br>* To require the meeting the prescribed standards within the prescribed time limit and accelerate the control of old polluting sources;<br>* To protect and rationally develop natural resources;<br>* To improve environmental economic policies and increase investment in environmental protection.<br>* To strictly enforce the environmental protection law.<br>* To actively carry out research into environmental sciences and develop environmental protection industry in a big way.<br>* To strengthen publicity and education and enhance the awareness of environment of the whole nation. |
| 27. "On the Current Economic Situation and Recommendations on Counter-measures" by the State Development Planning Commission, approved for circulation by the CPC central committee and the State Council (July 11, 1999; Ministry of Finance and State Taxation Administration issued documents on implementation) | * Starting from July 1, 1999, the fixed assets investment orientation regulatory tax shall be cut by half and shall be suspended by 2000.<br><br>* Starting from July 1, 1999, investment by enterprises in home-made equipment in technical transformation that conform to the state industrial policies can be used to offset business income tax according to the proportion of 40%. |

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| 28. Circular of the State Council on the scope of application of the preferential clauses concerning taxation for foreign-funded enterprises engaging in energy, communications infrastructure projects (July 2, 1999) | The 15% preferential income tax rate for foreign-funded enterprises in the open coastal areas, special economic zones and economic and technology development zones that are engaged in energy and communications projects has been extended to all places in the country. |
| 29. Catalogue of industries, products and technologies encouraged for priority development by the State at present and Indicative catalogue of industries for foreign investment worked out by the State Development Planning Commission and approved for issue by the State Council (issued on Dec. 31, 1997 and for trial implementation on Jan. 1, 1998) | * Catalogue of industries, products and technologies emphatically encouraged:<br>* Protection and development of water energy resources;<br>* Solar energy, geothermal energy, marine energy, garbage, biomass energy generation and large wind generators;<br>* Key technologies for energy conservation in buildings;<br>* Comprehensive utilization of resources;<br>* Comprehensive utilization of solid wastes;<br>* Large sewage water treatment projects;<br>* Indicative catalogue of industries for foreign investment:<br>* New energy (solar energy, wind energy, geothermal energy and tidal energy) power stations construction and operation;<br>* Energy conservation technologies;<br>* Technologies for regeneration and comprehensive utilization of resources. |
| ***II. China's current policies for promoting the development of renewable energy*** | |
| 30. State energy technology policies approved for issue by the State Council (1996) | * Actively develop and utilize new energy;<br>* Set up a rational rural energy structure and end serious energy shortage in rural areas as soon as possible. |

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| 31. Outlined Program for the Development of New Energy and Renewable Energy for 1996-2010 and Priority Development Projects for New Energy and Renewable Energy formulated by the State Development Planning Commission, the Science and Technology Commission and the Economic and Trade Commission. | * Put forward the objectives, tasks and priority development projects for renewable energy for 1996-2010. |
| 32. Standards and specifications | By the end of 1996, China had promulgated 30 state standards concerning renewable energy and rural energy, 6 trade standards and 3 sectoral technical specifications, including home biogas pits, large and medium-sized biogas projects, solar energy water heaters, solar house, solar dryers, solar stove, wind power generation, mini hydropower and energy-efficient stoves. |
| 33. Pricing of electricity generated by renewable energy | The electricity price is fixed by the government pricing department and the pricing system is very complicated. Before the mid-1980s, power plants (including hydropower stations) were built with government appropriations and the power generation cost and price were very low. Later on, state financing was changed into bank loans and principal and interests have to be paid. The electricity price for IPP was fixed by cost plus tax and profits during the period of repaying principal and interests.<br><br>At present, the prices of electricity generated by most hydropower stations that have gone on stream are on the low side, slightly higher than cost, 0.10 Yuan/kWh lower than thermal power. In 1994, the former Ministry of Power Industry provided that all power grids must purchase all the electricity generated by wind farms and the electricity must be priced according to the repayment of principal and interests. The portion above mean electricity price is shared by the whole power grid. In 1999, the State Development Planning Commission and the Ministry of Science and Technology confirmed this policy. The problem is that it is hard for small power grids with a bigger proportion of wind power to bear the higher cost. |

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| 34.Preferential loans | In 1994, China's commercial banks went commercialized and the State Development Bank and Agricultural Development Bank were opened as policy-based banks. At present the policy-based banks provide low-interest loans.<br><br>In 1987, the State Council decided to set up rural energy-oriented discount loans. The central finance provides the financing and 50% of the interest rate of the commercial banks is provided for renewable energy projects, including small wind generator manufacturing (the accumulative amount of loans of 50 million Yuan ) and wind farms construction (850 million Yuan in 1996), photovoltaic cell lines (10 million Yuan), solar energy heater production, and power generation by sugar cane sludge (planned annual figure is 100 million Yuan for 1996-2000) . |
| 35. Tax concession | * Tariffs and VAT in the import link. Tariff is zero for a complete set of wind generator import , tax rate for parts is 3%. VAT is (import product price + tariff) x 17% + VAT surcharge (urban construction and maintenance fees 5%~8%, education surcharge 3%) =VAT amount x 8%~11%.<br><br>* VAT and VAT surcharge. VAT is a common shared tax, which is 75% for the central and 25% for the localities and the basic tax rate is 17%. It is 6% for small hydropower, 13% for biogas. VAT surcharge=VAT x 8%~11, which is local tax. Local government has the right to exempt or reduce. It is 3% for wind power in Inner Mongolia, for instance.<br><br>* Enterprise income tax. Unified rate is 33%. It is free for enterprises acknowledged by the State as in the new and high-tech industrial zones for the first two years and the 15% is applied in the following two years. Enterprises with wastes as main raw materials are free from income tax within five years after operation. Starting from Jan. 1, 2000, for foreign-funded enterprises in the middle and western areas of the country, the 15% tax rate will be applied within three years after the current tax concession policy expires. If foreign-funded enterprises in eastern areas of China re-invest in the central and western areas of the country, they shall be regarded as foreign-funded enterprises if the investment proportion exceeds 25% and enjoy the corresponding treatment.<br><br>The above taxes, except tariff, are not accounted into cost. So they cannot motivate enterprises to improve technology and lower cost. Once they are removed, it would have a great impact on the enterprises. |

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| 36. Subsidy to renewable energy | Subsidy by the central government:<br>* Overhead expenses for management organizations, for use in demonstrative projects and training. It amounted to 9.2 million Yuan in 1990-1996.<br>* R&D subsidy. 500 million Yuan were used for this purpose in 1996-2000.<br>* Investment discount. At present, the State Economic and Trade Commission provides 120 million Yuan of discount loans for renewable energy and the Ministry of Water Conservancy provides 300 million Yuan of discount loans for small hydropower projects per year.<br><br>* Funds for fighting poverty and for rural electrification. In 1991-1995, 7 million Yuan were invested in Tibet, which were used to build four photovoltaic power-generating systems, with a total capacity of 85kW.<br><br>Subsidy by local governments:<br>* R&D subsidy. 300,000 Yuan in Inner Mongolia; one million Yuan in Xinjiang and 500,000 Yuan in Qinghai yearly.<br><br>* Subsidy to users. Inner Mongolia subsidizes 200 Yuan for buying a set of 100W wind generator or 16W photovoltaic system. The total subsidy in 1996 was 1.5 million Yuan. Xinjiang subsidies 50-200 Yuan for buying each set. Qinghai subsidizes 300 Yuan for buying a set of photovoltaic system. The subsidy comes from the money raised by collecting additional 0.02 Yuan/kWh of electricity charges. In Gansu, the subsidy for the purchase of each set of photovoltaic system is 300 Yuan, coming from the local finance and photovoltaic funds.<br><br>* Rural energy construction. In 1981-1996, provincial, county and township governments spent a total of 2.06 billion Yuan. |
| 37. R&D | There are 150 organizations doing R&D of renewable energy, manned by more than 3,000 scientists and technicians. Now the Ministry of Science and Technology devotes 100 million Yuan annually to projects tackling difficult problems with regard to renewable energy. |
| 38. Technology diffusion | Established rural energy technical extension system in the whole country. There were 7902 organizations responsible for the spread of the technologies in 1998, manned by 24,700 people. There were also 9274 professional technical service teams with 80,200 people. |

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| 39. Integral construction plans for rural energy at the county level | With county as the basic unit, work out plans for energy, economy and environment and fix execution plans and technical line in the light of local conditions and promote a coordinated development between energy and economy, society and environment with focus on the development and utilization of renewable energy. Achievements are good. In 1998, there were 204 counties investing 3.85 billion Yuan, including 310 million appropriated. |
| 40. Training | Established a rural energy training network, with training centers in North China, Northeast China, Northwest China, East China and Central China, which trained 378,000 people in 1997 and 1998. |
| 41. Displaying the role of non-governmental organizations | Non-governmental organizations associated with renewable energy include: the China Rural Energy Industry Association, Rural Energy Sub-Committee, New Energy Sub-Committee and Geothermal Sub-Committee of the China Energy Research Society, Chinese Solar Energy Society, China Hydropower Society, China Forestry Sciences Society and the China Biogas Society.<br><br>These organizations play a role in advising on policy decision making, project assessment, publicity, education and training, information service and international exchange. |
| 42. Public involvement | To enhance the understanding of the public of renewable energy through publicity activities and large scaled training; develop technologies best suited to China's conditions (energy efficient stoves, home biogas pits, ecological agricultural mode with biogas as the bond and mini-hydropower) on the basis of technical creation by the people; a successful case of direct participation of residents in working out renewable energy development plans is the 12 types of comprehensive construction of rural energy in 1986-1990, which had the participation of thousands of farmers and rural technicians. |

## III. Renewable Energy Policy: Foreign Experience

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| 43. Legislation | * USA: PURPA, 1978, which requires power companies to buy renewable energy power according to avoidable cost;<br><br>* EPACT, 1992, which requires the renewable energy supply to increase by 75% by 2010 over 1988 and grants tax credits and tax deductions on investment in renewable energy development;<br><br>* State comprehensive energy strategy (1998), which requires the accelerated technical development of renewable energy power, with the power generating capacity by renewable energy other than hydropower to reach at least 25GW by 2010; CCAP, 1993; Federal Hydropower Law, Geothermal Law and Ocean Thermal Energy Conversion Law.<br><br>* Germany: Power supply law (1990), which provides that power companies may buy electricity from renewable energy power producers at a price 65-90% of the average user price.<br><br>* UK: Non-fossil fuel obligation (NFFO, 1990), which requires that power companies to ensure a certain proportion of power generated by renewable energy, renewable energy power plants, which sign contracts with power companies through bidding, will be subsidized in electricity price. Competition stimulates expansion of scale and drop in cost. In 1990, the mean price for wind power bidding projects was 17 US cents/kWh. But it dropped to 6 cents by 1997 and subsidy dropped from 13 US cents to 2 US cents per kWh. |

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| 44. Pricing | * Price of renewable energy power connecting to power grid is fixed according to avoidable cost of power companies;<br>* Fixed encouragement price. It provides that for a certain period of time (say 10 years), power companies may fix the prices of renewable energy power according to a certain proportion of the average price of electricity, with differences to be shared by users. The wind power price is 90% of the average electricity charge in Germany and 85% in Denmark.<br>* Provides that power companies must have a certain proportion of electricity from renewable energy and fix the prices through bidding, with the balance in prices to be shared by end-users. UK, Ireland and France implement the system.<br>* Net metering. Users can pay electricity charges for the part of electricity used after offsetting that generated by their own renewable energy. There are 23 states in the United States implementing the system.<br>* Green electricity price. Users volunteer to pay fairly high prices for electricity generated by renewable energy. In the state of California, 1% of the users buy green power. |
| 45.Systems Benefit Charge (SBC) | The power department of the State of California has implemented a public benefit program after entering the competitive market to protect renewable energy, energy efficiency and low-income earner subsidy. This is done by collecting additional 3% charges from users to establish a trust fund. In 1998-2001, it raised US$1.41billion, of which US$540 million are used to support renewable energy program, including subsidy to investment in renewable energy projects, incentives for generating power by using renewable energy, low interest loans and credit guarantee, energy and technology research and rebates for users. |
| 46. Demand-side management and integrated resources program | Renewable energy is incorporated in the demand-side management and integrated resources program as a resource. Some states of the United States use most of the SBC funds for demand-side management. |
| 47 Voluntary agreement | The government sign agreements with companies or trade associations, by which companies undertake obligations to reduce $CO_2$ discharge or energy conservation and the government grants investment subsidy or tax concession. This is an effective policy tool. There are more than 200 such voluntary agreements in OECD countries. US voluntary agreements include energy star buildings and green lighting program. |

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| 48. Energy auditing of medium-sized and small enterprises | US Energy Department set up an energy analysis and diagnostic center (EADC) in 1976, which provides free energy auditing service for medium-sized and small enterprises in the manufacturing. The services are funded by the government and implemented by 26 state universities and four non-governmental research institutions. More than 7,700 auditing projects have been completed since 1981. |
| 49. Industrial energy efficiency network | Power supply in Norway almost all comes from hydropower (99.8%). In order to promote a rational utilization of hydropower resources, the Water and Energy Resources Department of the Petroleum and Energy Ministry established an industrial energy efficiency network, covering 13 trades, 500 companies, which consume 70% of the industry energy.<br><br>Through the network, it provides enterprises with information, consulting service and training to help them enhance the ability of conserving energy, subsidize energy auditing, technology development and demonstrative projects (the maximum has reached 50%), formulate energy consumption standards for industries, publish energy consumption reports. The industries involved in the program reported a 1.4% drop in average annual energy consumption. |
| 50. Government procurement | US Federal Government spendsUS$8 billion on energy yearly. Related laws require the government to procure homemade energy-efficient products and "green products", such as it requires the Federal Government to procure 100,000 clean fuel motor vehicles (using natural gas, electricity and biomass fuel) by 2005. This will effectively promote the development of clean motor vehicles and stimulate the investment in related infrastructure facilities. |

## APPENDIX B: PROSPECTS OF CHINA'S RENEWABLE ENERGY: TWO SCENARIOS

### *I. Current conditions of supply and demand of energy*

After years of energy shortages, China now has an energy surplus. In 1998, China's coal output ranked first in the world. Oil output ranked fifth and electricity output second. Interestingly, however, China has now become a major oil importer. In 1999, China's coal output was 1045 Mt; crude output, 160 Mt; natural gas output, 25.2B$m^3$ ; and electricity output, 1239.3TWh.

Energy occupies a very important position in China's social and economic development. The total energy spending by end users in 1997 reached 1234.500 billion Yuan.

In the recent 20 years, China has made marked progress in energy efficiency and conservation. The average annual rate of energy conservation (drop of average annual energy intensity) reached as high as 4.4% in 1981-1997, 3.7 times the average level of OECD countries. If calculated according to the official exchange rate, unit GDP energy consumption (energy intensity) was 2.8 times the average of OECD countries and nearly twice as much as the world average.

**China's Energy Supply, Consumption and Trade in 1998** [1]

| - | Coal | Petroleum | Natural gas | lectricity | Total of primary energy |
|---|---|---|---|---|---|
| Proven reserves | | | | | |
| China | 114.5Bt | 3.8Bt | 1.37 $10^{12}m^3$ | | |
| World | 984.2Bt | 143.4Bt | 146.4 $10^{12}m^3$ | | |
| Output | | | | | |
| China | 1250Mt | 161Mt | 23.28B $m^3$ | 1167TWh | 1240Mtce |
| World | 4550Mt | 3519Mt | 2271.8B $m^3$ | ? 4000TWh | 12110 Mtce |
| China's ranking | 1 | 5 | 19 | 2 | 3 |
| Consumption | | | | | |
| China | 615Mtce2219M | 190Mt | 21.4B $m^3$ | 1001TWh | 1322 Mtce |
| World | tce | 3389Mt | 2240.5B $m^3$ | ? 12400TWh | 12110 Mtce |
| Import & export | | | | -- | |
| China | Exp.32.29Mt<br>Imp.1.58Mt | Exp.19.84Mt<br>Imp.49.06Mt | | | |
| World | 524Mt | 1994Mt | 446.1B $m^3$ | | |

China's per capita energy consumption, especially electricity, is very low, averaging one sixth of the average of OECD countries and 54% of the world average. Average per capita electricity consumption was one ninth of OECD countries and 45% of the world average.

**International Comparison of Key Energy Indices**[ii]

| | China | US | Japan | OECD | World |
|---|---|---|---|---|---|
| Energy intensity in 1996, kgce/1997US$ | l.674 | 0.549 | 0.232 | 0.439 | 0.567 |
| 1997 per capita energy consumption, kgce | 1118 | 11530 | 5820 | 6580 | 2080 |
| 1997 per capita power output, kWh | 919 | 13739 | 8132 | 8021 | 2090(1996) |
| Drop of annual energy intensity | 4.4 (1981-1997) | 1.4 (1973-1996) | 1.2 (1973-1996) | 1.2 (1973-1996) | |
| $CO_2$ discharge, Mt-C in 1996 | 805 | 1463 | 291 | 2980 | 5983 |

## *II. Two Scenarios for Energy Supply and Demand in China*

Since the mid-1980s, China has carried out research in energy demand and supply forecasts. Among them is the "Study of China Energy Strategy (2000-2050)" organized by the original Ministry of Energy. More than 60 research institutes, universities, academic groups and central and local governments participated in the work and the number of principal researchers came to more than 200. The study lasted for six years and was completed in 1996. The "Study of China's Energy Strategy for Sustainable Development" completed by the China Academy of Engineering is the latest research achievement.

In order to know the real situation of coal consumption and changes in the demand of coal, the State Planning Commission and the original Ministry of Coal Industry organized a joint investigation group to carry out the "Survey of China Coal Consumption and Forecast Study." The group surveyed coal-using industries and coal production enterprises in 25 provinces, municipalities and autonomous regions. The survey shows that the national coal consumption in 1996 was 1346Mt, 91 Mt less than the 1437Mt published by the State Statistical Bureau. It was 1311 Mt in 1997, 81Mt less than the published figure of 1392 Mt.

The report forecasts that the demand for 2005 (not including net export) will be 1360 Mt – the same as the 1996 level – and demand by 2010 will reach 1500Mt. The original planned output for 2000 was 1400Mt. This means that coal demand has been much reduced. The forecast and planned output put forward in the mid-1990s must be adjusted downward, and the estimated 2000 coal output will not occur until 2010. This will inevitably have a major impact on the prospects of China energy demand and supply and on future $CO_2$ discharge.

This report arrives at the forecast result for energy demand and supply in 1998-2050 on the basis of the above research achievements and by consulting the latest data.

**Hypotheses**

* Population growth and structural change. The forecast model is based on multiple schemes according to total fertility. The middle scenario is based on a total population of 1.54 billion by 2050, with urban population accounting for 70% and aged people of over 60 years accounting for 34%.

* Economic growth and structural change. Systems dynamic model is used to forecast the trend of economic and social changes. In order to realize the goal of achieving the level of middle developed countries by the mid-21st century, it is imperative and possible to keep a fairly high economic growth, which is 7% for 2000-2020, 3.7% for 2020-2050. The percentage of the tertiary industry rises from 35% in 2000 to 70% in 2050.

* Technical progress. Suppose the production of energy consuming products and energy using equipment of end-users have already adopted or are going to adopt the most advanced commercialized technology, the energy intensity drops sharply, from 386tce/million Yuan of GDP in 2000 to 77tce/million Yuan GDP by 2050 (1990 price).

* Supply capacity. Apart from petroleum and natural gas, suppose the demand of energy sources will be satisfied by domestic development. The future supply capacity is based on economically exploitable resource, taking into consideration technical progress that can increase the economically exploitable reserves.

* Environmental factors. The coal demand growth will be slowed as much as possible and natural gas and renewable energy sources will be developed in a big way.

**Table. Hypotheses of Energy Demand Forecast**

| GDP growth, %/yr | | Tertiary Industry % | | Total population (mil.) | Urban population (%) | Aged population % | Energy intensity, tce/million Yuan (GDP) |
|---|---|---|---|---|---|---|---|
| 2000~ 2010 | 7.5 | 2000 | 35 | 1300 | 35 | 14 | 386 |
| 2010-2020 | 6.4 | 2010 | 41 | 1420 | 47 | 19 | 260 |
| 2020-2030 | 4.8 | 2020 | 46 | 1490 | 56 | 24 | 180 |
| 2030-2040 | 3.6 | 2030 | 52 | 1530 | 62 | 28 | 130 |
| 2040-2050 | 2.8 | 2040 | 58 | 1540 | 66 | 31 | 99 |
| | | 2050 | 70 | 1540 | 70 | 34 | 77 |

*Note: Aged people are referred to as population of 60 years and above.*
*Reference: 1. Research group: Study of China Energy Strategy (2000-2050), China Power Publishing House, May 1997.*
*2. Yao Yufang, He Juhuang et al, China's Economic Growth and Sustainable Development, Social Sciences Document Publishing House, Aug. 1998.*

## Scenario Designs

Two models are adopted for the forecast of energy demand for 2000-2050. The business as usual or "BAU" scenario used the above hypotheses based on the current trend of development. The ARE scenario or accelerated renewable energy scheme, assumes a policy environment favorable to renewable energy. The following table illustrates the two scenarios.

**Table: Forecast of Primary Energy Demand for 2000-2050**[2]

| | **Real amount 1998** | **2010** | **2020** | | **2050** | |
|---|---|---|---|---|---|---|
| | | | BAU | ARE | BAU | ARE |
| Coal,Mt Mtce | 1310.0<br>936.0 | 1500.0<br>1071.0 | 2100.0<br>1500.0 | 1800.0<br>1285.0 | 2500.0<br>1786.0 | 1400.0<br>1000.0 |
| % | 60.6 | 53.8 | 54.6 | 49.2 | 43.1 | 27.4 |
| Petroleum, Mt | 190.0 | 280.0 | 360.0 | 320.0 | 740.0 | 520.0 |
| Mtce | 270.0 | 400.0 | 514.0 | 457.0 | 1057.0 | 743.0 |
| % | 17.5 | 20.1 | 18.7 | 17.5 | 25.5 | 20.4 |
| Natural gas, $Bm^3$ | 21.4 | 100.0 | 160.0 | 200.0 | 250.0 | 300.0 |
| Mtce | 28.5 | 133.0 | 213.0 | 266.0 | 333.0 | 400.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| % | 1.8 | 6.7 | 7.8 | 10.2 | 8.0 | 11.0 |
| Nuclear power, GW | 2.1 | 20.0 | 40.0 | 50.0 | 120.0 | 240.0 |
| TWh | 14.1 | 120.0 | 250.0 | 313.0 | 720.0 | 1440.0 |
| Mtce | 5.3 | 40.0 | 80.0 | 100.0 | 216.0 | 432.0 |
| % | 0.3 | 2.0 | 2.9 | 3.8 | 5.2 | 11.9 |
| | | | | | | |
| Renewable energy, Mtce | 304.6 | 347.8 | 441.1 | 502.9 | 756.0 | 1068.0 |
| % | 19.7 | 17.4 | 16.0 | 19.3 | 18.2 | 29.3 |
| Total, Mtce | 1550.0 | 1991.8 | 2745.1 | 2606.9 | 4148.0 | 3643.0 |
| % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $CO_2$ discharge, Mt-C | 793.0 | 998.0 | 1385.0 | 1230.0 | 1921.0 | 1245.0 |

*Notes: 1. Apart from petroleum and natural gas, the demand for other forms of energy is equal to the domestic supply capacity.*
*2. BAU (Business as usual) is based on the current trend of development while ARE is accelerated renewable energy.*
*3. Coal demand does not include export.*
*4. Hydropower does not include pump storage power stations.*
*5. Nuclear power and power generated by renewable energy is concerted into standard coal according to the heat consumption of thermal power stations (gce/kWh). It is 373 for 1998, 330 for 2010, 320 for 2020 and 300 for 2050.6.$CO_2$ discharge factor (t/tce): 0.68 for coal, 0.54 for petroleum and 0.41 for natural gas.*

*Reference: 1. Research group: Study of China's Energy Strategy (2000-2050), China Power Publishing House, May 1997.*
*2. Academy of Engineering, Study of China's Energy Strategy for Sustainable Development, Dec. 1998.*
*3. joint investigation group of State Planning Commission and the original Ministry of Coal Industry: Survey of Coal Consumption and Study of Forecast, 1999.*
*4.. 1998-1999, China rural Energy Yearbook, China Agricultural Publishing House, Nov. 1999..5. State Statistical Bureau.*

The forecast results show:

* Total demand is huge and the structure improves markedly. According to the BAU scheme, the demand of primary energy by 2050 will be 4148 Mtce, 1.7 times more than in 1998. The percentage of coal may drop to 43.1% and renewable energy18.2%. The total energy demand in the ARE scenario is 12.2% less than the BAU scenario by 2050. Coal demand will drop by 44%, with its percentage dropping to 27.4%. Renewable energy increases 41%, with percentage to rise by 29.3%.

* Per capita energy consumption will be very low. According to the BAU scenario, the average annual per capita energy consumption by 2050 will be 2690 kgce. It is therefore necessary to adopt advanced technology to raise energy efficiency and seek low energy consumption way of living and consumption structure best suited to the Chinese conditions.

* Renewable energy is likely to become the main energy source. According to the ARE scenario, the development and utilization of renewable energy by 2050 may reach 1068 Mtce, close to the fossil fuel and nuclear power consumption of 1240 Mtce in 1998. The percentage of renewable energy in the primary energy consumption may reach 29.3%, exceeding coal to become the biggest energy source.

* The ARE scenario may slow greatly the increases of $CO_2$ discharge. For China, the future of fairly high economic growth will inevitably increase the energy demand and it will take a long time to lower coal consumption and develop renewable energy. Implementation of the ARE scenario may accelerate the development of renewable energy and intensify energy conservation, thus greatly reducing the $CO_2$ discharge, with the $CO_2$ discharge for 2020 being 1230Mt-C. This level would be far lower than the 2031Mt-C as predicted by DOE/EIA of the United States and also less than the 1346Mt-C of the United States in 1990 and the predicted 1975Mt-C for 2020. So China's $CO_2$ discharge should not exceed that of the United States before 2020.

### *III. Prospects for the Development of Renewable Energy Resources*

Putting together the forecasts of the development of all types of renewable energy, it is estimated that the total usable amount of renewable energy may increase from 304.6Mtce in 1998 to 347.8 Mtce by 2010. The figure could then rise to 441.1-502.9Mtce by 2020 and then to 756.0-1068.0 Mtce by 2050. The installed capacity may increase from 66.2 GW in 1998 to 118.0 GW by 2010, up to 184.2-218.3 GW by 2020 and still up to 458.5-707.0 GW by 2050.

**Table. Forecast of Development and Utilization of Renewable Energy in 1998-2050**

| | Real amount 1998 | 2010 | 2020 | 2020 | 2050 | 2050 |
|---|---|---|---|---|---|---|
| | | | BAU | ARE | BAU | ARE |
| Hydropower, GW | 65.1 | 110.0 | 160.0 | 180.0 | 260.0 | 320.0 |
| TWh | 208.0 | 350.0 | 500.0 | 563.0 | 760.0 | 935.O |
| Mtce | 77.6 | 116.0 | 160.0 | 180.0 | 230.0 | 280.0 |
| Of which, small hydropower: | | | | | | |
| GW | 25.2 | 35.0 | 50.0 | 55.0 | 70.O | 75.0 |
| | 80.0 | 112.0 | 160.O | 176.0 | 224.0 | 240.0 |
| TWh | 29.8 | 37.0 | 51.2 | 56.3 | 67.2 | 72.0 |
| Mtce | | | | | | |
| Bio-energy, Mtce | 224.5 | 210.0 | 230.0 | 250.0 | 275.0 | 310.0 |
| Of which, traditional use | | | | | | |
| Use by new tech | 222.0 | 140.0 | 90.0 | 90.0 | 40.0 | 40.0 |
| Of which, | 2.5 | 70.0 | 140.0 | 160.0 | 235.0 | 270.0 |
| power generation , GW | | | | | | |
| TWh | 0.8 | 3.0 | 10.0 | 15.0 | 30.0 | 50.0 |
| Mtce | 2.0 | 12.0 | 40.0 | 60.0 | 120.0 | 200.0 |
| | 0.75 | 4.0 | 12.8 | 19.2 | 36.0 | 60.0 |
| Solar energy Mtce | 2.2 | 15.2 | 36.0 | 50.0 | 161.0 | 298.0 |
| Water heater : $Mm^2$ | 15.0 | 100.0 | 200.0 | 250.0 | 400.0 | 600.0 |
| | 1.8 | 12.0 | 24.0 | 30.0 | 48.0 | 72.0 |
| Mtce | 15.0 | 100.0 | 270.0 | 400.0 | 1000.0 | 2000.0 |
| Solar house:$Mm^2$ | 0.37 | 3.0 | 8.1 | 12.0 | 30.0 | 60.0 |
| | -- | 0.1 | 1.0 | 2.0 | 10.0 | 20.0 |
| Mtce | -- | 0.2 | 2.0 | 4.0 | 20.0 | 40.0 |
| Thermopower, GW | -- | 0.1 | 0.8 | 1.5 | 8.0 | 16.0 |
| TWh | | | | | | |
| Mtce | 0.013 | 0.15 | 4.0 | 8.0 | 100.0 | 200.0440.0 |
| Photovoltaic power, | 0.03 | 0.33 | 8.8 | 17.8 | 220.0 | 150.0 |
| GW | 0.01 | 0.12 | 3.2 | 6.4 | 75.0 | |
| TWh | | | | | | |
| Mtce | | | | | | |
| Wind power, GW | 0.248 | 4.0 | 6.0 | 8.0 | 50.0 | 100.0 |
| TWh | 0.66 | 10.9 | 17.4 | 23.2 | 156.0 | 312.0 |
| Mtce | 0.25 | 4.0 | 6.0 | 8.0 | 44.0 | 88.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Geothermal | | | | | | |
| , Mtce | 0.44 | 2.0 | 6.0 | 10.0 | 25.0 | 50.0 |
| Of which, Power, GW | 0.028 | 0.1 | 0.2 | 0.3 | 0.5 | 1.0 |
| | 0.11 | 0.5 | 1.0 | 1.5 | 2.5 | 5.0 |
| TWh | 0.04 | 0.17 | 0.3 | 0.5 | 0.8 | 1.5 |
| Mtce | | | | | | |
| Marine power, GW | -- | 0.6 | 3.0 | 5.0 | 8.0 | 16.0 |
| | -- | 1.6 | 9.0 | 15.0 | 24.0 | 48.0 |
| TWh | -- | 0.6 | 3.0 | 5.0 | 21.0 | 42.0 |
| Mtce | | | | | | |
| Total, | 304.6 | 347.8 | 441.1 | 502.9 | 756.0 | 1068.0 |
| Mtce | | | | | | 707.0 |
| Of which, | 66.2 | 118.0 | 184.2 | 218.3 | 458.5 302.5 | 2100.0 |
| power generation: GW | 210.8 | 375.5 | 578.2 | 684.5 | 418.5 | 643.5 |
| TWh | 78.7 | 126.0 | 192.1 | 230.0 | | |
| Mtce | | | | | | |

*Notes: 1. BAU scheme is based on the current development while the ARE scheme is accelerate development renewable energy.*

*2. The forecast of the development and utilization of all types of renewable energy takes into account resources potential, economic and social development, technical progress and competitiveness against conventional energy and other factors.*

*3. Small hydropower refers to hydropower stations each with an installed capacity of less than 25 MW.*

*4.Application of new technologies in using biomass energy includes biogas, gasification, liquefaction and power generation.*

*5. Wind power in 1998 includes wind farms that have gone on stream, which was 224MW and 605GWh, 156,000 small and mini windmill generators: 18MW and 36GWh.*

*6. Each square meter of heat collection areas of solar water heater provides 120kgce energy while each square meter of passive solar house may save 25kgce annually (during heating season).*

*7. Annual hours of utilization of renewable energy power generating equipment: 3200 hours for small hydropower, 4000 hours for bio-mass energy power generation, 1,800 hours for solar heat power generation, 2,200 hours for photovoltaic power generation, 2,700 hours for wind power by 2010, 2,900 hours for 2020 and 3,100 hours for 2050, and 5000 hours for geothermal power.*

*8. Electricity output is converted into standard coal according to the heat consumption of thermal power stations (gce/kWh) 373 for 1998, 330 for 2010, 320 for 2020 and 300 for 2050.*

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[1] From: *China Statistics Year Book 1999*. State Statistics Bureau, China Statistics Publishing House, September, 1999. *Statistical Review of World Energy*, 1999, BP Amoco. Also: "Coal and Natural Gas Competition in the APEC Economy." APEC, Bangkok, August, 1999.

[2] Op. Cit i. and iv. Also: "New and Renewable Energy Development Plan," SETC, November 1999.