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# Analysis of China's Renewable Energy Development under the Current Economic and Technical Circumstances

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Abstract

*At present, the development of renewable energy relies mainly on government support. The government invests in a considerable number of projects to improve public welfare and to assist in poverty relief. If China is to replace fossil fuels on a large scale with renewable energy sources, the production costs and prices of renewable energy must be brought down. All countries are facing the challenge of moving to a more secure and low-carbon energy system without weakening economic and social development. In this regard, China is facing an even greater challenge in terms of economic cost, as cheap coal remains the main energy form. Technical innovation and industrialization in the area of renewable energy is an important means of lowering cost. China is in for a period of high-speed development of its economy and the rising demand for energy is irreversible. If the technical progress and development speed of renewable energy lags behind the growth in demand, it will be difficult to realize the improvement of its energy structure.*

Key words: China's renewable energy policy, energy supply security, fossil fuels
JEL codes: O53, P41, Q28

## I. Introduction

Renewable energy can be generated from water, wind, sunlight, biomass, geothermal heat and tidal waves. Compared with fossil energy sources, such as coal and petroleum, renewable energy sources emit less pollution to the environment, and possess the potential for endless utilization. It is, therefore, important to improve the energy structure of China and energy supply security, to satisfy the constantly increasing energy demand and to realize universal

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service of energy sources.

China is in a period of accelerated industrialization and urbanization, and energy demand is rising steadily. Since 2002, energy consumption has been growing by more than 10 percent annually. The total energy consumption in 2006 reached 2462.70 million tons of standard coal (1 ton of raw coal is equal to 0.714 tons of standard coal), 4. 3 times the consumption in 1978, or 1 billion tons of standard coal more than in 2000. China's energy production has also increased greatly. In 2006, China's primary energy production totaled 2210.56 million tons in terms of standard coal, 3.52 times that of 1978. However, due to the increasing energy consumption, China's net import of energy in 2006 reached 202.46 million tons of standard coal. This included net imports of 138.838 tons of crude oil, approximately 50 percent of the country's total oil consumption. Most forecasts show that by 2020 oil shortages could reach 80 000 bbls/day and the dependence on oil importation by that time is likely to reach over 70 percent of total consumption (Brookings Institution, 2006). According to the SCIO (2008), China's coal reserves can be mined for another 48 years, oil reserves can be extracted for another 12.1 years and natural gas for 41.8 years. China is facing great challenges in its sustainable development of energy sources.

The coal-based energy structure has brought huge pressure to bear upon China's environment. Fossil fuels account for more than 90 percent of energy consumption in China. Of this, coal accounts for over 70 percent, and is responsible for 85 percent of the $CO_2$ emissions, 74 percent of the $SO_2$ discharge, 60 percent of $NO_x$ discharge and 70 percent of the soot in the air. At present, China is ranked number 1 in the world in terms of the discharge of $SO_2$ and $CO_2$. This explains why over 40 percent of China's land area is affected by acid rain.

However, China is rich in renewable resources. Development of such resources can not only ensure energy supply security, improve energy structure and reduce negative effects on the environment, but also end rural energy poverty. This is where the special significance of developing renewable energy lies in China in contrast to developed countries.

As China's energy consumption statistics do not include the direct consumption of biomass energy, the proportion of renewable energy in the energy consumption structure is lower than that of developed countries. Despite all this, the Chinese Government has set the goal of raising the proportion of renewable energy in total energy consumption to 10 percent by 2010 and up to 15 percent by 2020. China considers the development of renewable energy to be an important means of improving its energy consumption structure. It has also, through the creation of new laws, prioritized the development of renewable energy.

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Section II of the present paper is an overview of the policy measures implemented over the past decade to support the development of renewable energy. The section includes a comparison of the goals set for different periods and a classification of policy measures. Section III provides an analysis of the current conditions and characteristics of renewable energy development and an assessment of the implementation results of the development goals and policy measures. Section IV provides a conclusion, which outlines some problems associated with the development goals and with the policy measures being pursued.

## II. Goals and Policy Measures for the Development of Renewable Energy

### 1. Renewable Energy Development Programs and Goals

China began to compile its first renewable energy development program in 1996: the "New and Renewable Energy Development Program 1996–2010." China has established four development programs focused on new energy and renewable energy sources. These are: "An Outlined Program for the Development of New and Renewable Energy" (1995), the "10th Five-Year Plan for the Development of New and Renewable Energy Industry" (2001), the "11th Five-Year Renewable Energy Development Program" (2006) and the "Medium- and Long-Term Development Program for Renewable Energy" (2003).

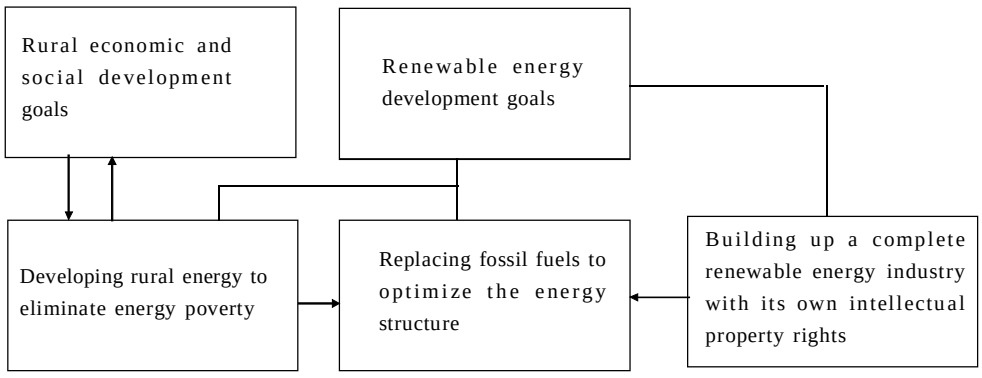
The first new and renewable energy development program was implemented at a time when 28 counties, nearly 1000 rural villages, thousands of islands and 120 million people did not have access to electricity; more than 900 million people living in the rural areas suffered from energy shortages in their daily living. Forests were over-logged, vegetation was damaged, and the ecological environment had deteriorated. All these factors seriously hampered rural economic and social development. Therefore, the first development program emphasized rural energy supply. The principle was to: "develop and spread the use of solar heat, wind power, geothermal heat, tidal energy, biomass energy and other clean energy forms according to local conditions." The development goals set covered areas for the plantation of firewood forests, biogas generation from biomass, small hydropower stations, the use of solar energy, wind energy and wind mills, and the development of geothermal heat.

By 2000, China's economic development had ascended to a new level, with the per capita income reaching US$1000 and the progress of urbanization having gained much ground. The rural energy supply began to improve. The 10th Five-Year Development Program for the New and Renewable Energy Industry" set the general goals for the total production

of new and renewable energy. The program increased the goals for the generating capacities of wind farms, solar energy equipment and hydrogen generating equipment, as well as goals for the development of the energy industry and equipment R&D.

The "Medium- and Long-Term Development Program for Renewable Energy" and the "11th Five-Year Development Program for Renewable Energy" still prioritized the development of water power, biomass energy, wind power and geothermal heat and tidal wave energy, leaving out hydrogen generation. In the 11th five-year development program, the development of wind power, solar heat and biomass energy received considerable attention. Wind and solar power needed to develop to the point where power grid access was possible; and biomass energy needed to develop in the direction of generating electricity, and gas, solid and liquid fuels. Unlike for the previous development programs, for the "Medium- and Long-Term Development Program" and the "11th Five-Year Development Program" the replacement of fossil fuel with renewable energy was the first development goal, to optimize the energy consumption structure. This indicates that China has evolved to a development model for renewable energy entirely different from those of the preceding periods; that is, it is on a path of large scale and industrialized development. China has to rely on its renewable energy industry to raise the proportion of renewable energy in the total energy consumption structure. The programs have set goals for the development of the renewable energy industry, so that ultimately renewable energy technologies can be used in large-scale. The renewable energy development goals generally cover three aspects (see Figure 1): developing rural energy to eliminate energy poverty; replacing fossil fuel to optimize the energy structure; and developing and improving the renewable energy industry with its own intellectual property rights. In

**Figure 1. China's Renewable Energy Development Goals and the Mutual Relationship between Renewable Energy and Fossil Fuels**




Source: Compiled by author.

## Table 1. Targets Set in the Renewable Energy Development Program, 2000–2020

| Renewable energy | 2000 | 2005 | 2010 | 2020 |
|---|---|---|---|---|
| Converted to standard coal (in million tons) | (298) | 10th five-year program does not include small hydropower and biomass energy [13] | (390) 300, {300} | {600} |
| Hydropower installed capacity (million kW) | | | 190 {190} | {300} |
| Of which: small hydropower installed capacity (million kW) | (19.855) | | (27.88) {50.00} | {75.00} |
| Biomass power installed capacity (million kW) | (0.05) | | (0.30) 5.50 {5.50 } | {30.00 } |
| Wind power installed capacity (million kW) | (0.30–0.4) | [1.2 grid-connected] | (1.00–1.10) 10 grid-connected, 0.75 non-grid connected7.5 {5.00} | {30.00 } |
| Solar power installed capacity (million kW) | To build off-grid solar PV power stations in 9 counties without access to electricity in Tibet | Cumulative amount to reach 53 MW | 0.30 {0.30 } | {1.80 } |
| Annual biomass solid fuel utilization (million tons) | | | 1.00 {1.00} | {50.00} |
| Annual biogas utilization (million $m^3$) | (2260) | Number of large biogas digesters to reach 2000 million $m^3$ in 10th 5-year plan period | (4000) 19 000 million, including 4000 million large biogas digesters {19 000} | {44 000} |
| Annual utilization of biodiesel (million tons) | | | 0.20 {0.20} | {2.00}. |
| Annual utilization of biofuel ethanol (million tons) | | | 3.00 {annual utilization of fuel ethanol with non-cereals as raw materials, 2.00 } | {10.00} |
| Solar heat collector (million $m^3$) | Equivalent to 1.23 million tons of standard coal | [10th 5-year plan: 64] | 150 {150 } | {300 } |
| Of which, rural areas (million $m^3$) | | | {50} | {100} |
| Geothermal heat | (0.88 million tons of standard coal) | (For 2005, 20 million $m^3$) | Heat supply: 30 million $m^3$, hot water supply: 0.60 households (1.51 million tons of standard coal) {4 million tons of standard coal} | {12 million tons of standard coal} |
| Hydrogen energy | | | (5000 $m^3$ /day) | |
| Marketable firewood forest base (million ha) | (6.40) | | (13.40) | |
| Tidal wave power installed capacity (million kW) | | | | {0.10 } |

Sources: Compiled by author. Figures in parentheses come from the New and Renewable Energy Development Program, 1995; figures in square brackets come from the 10th Five-Year Program for the Development of New and Renewable Energy Industry, 2001; figures in curly brackets come from the Medium- and Long-term Development Program for Renewable Energy, 2003; and figures without brackets come from the 11th Five-Year Development Program for Renewable Energy, 2006.

Note: PV, photovoltaic.

Figure 1, arrows represent supporting relationships.

All the development programs set specific quantity targets according to the development status and conditions of the time, as is shown in Table 1. Generally speaking, the medium-term and long-term program serves as a guide to a five-year development period, with the targets for later periods revised on the basis of the implementation of the previous development targets. The changes in the target projects and values in Table 1 show that the development of renewable energy is moving toward concentration on hydropower, wind power, solar power and biomass energy, and that the targets for wind power and solar energy have adjusted steadily upward due to their rapid development. However, the total target for 2010 has been lowered from 390 million tons to 300 million tons in terms of standard coal.

The targets for the development of renewable energy technology and equipment can be summarized as: putting emphasis on improving the technical level and building a complete industrial system for the present stage. Mature technologies should realize large-scaled intensive production, with complete production and service systems. Tasks for 2010–2020 are to intensify localization of R&D of renewable energy technology and equipment and to establish a complete industrial system and greatly lower the cost of renewable energy development and utilization.

## 2. Law and Policy Measures

Compared with conventional fossil fuels, the development of renewable energy, although with high positive externalities, is costly. Some renewable energy sources, such as wind and sunlight, are poor in terms of stability of power generation, enjoying no competitive advantages in cost and price. Under the current economic and technical conditions, without government support in the implementation of its policies, it would be difficult for the development of renewable energy to progress rapidly.

The rural energy development target is an important component of rural economic and social development. Since the beginning of the 1980s, China has concentrated on the development of water power and building small hydropower stations in a bid to resolve the problem of rural areas without access to electricity. Since the beginning of the new century, China has launched the "Bright Project," the "Electricity to Rural Areas Project" and the "Small Hydro Power to Displace Fuel Project" in rural areas. The state has set up a special development fund to support projects utilizing renewable energy in the rural and livestock breeding areas as well as in the building of independent power systems for remote areas and offshore islands.

To scale up renewable energy development and to promote the development of the renewable energy industry, in recent years China has promulgated in quick succession a

number of measures, including making laws, providing guarantees and incentives for the production and utilization of renewable energy, promoting scientific research and formulating technical standards. For instance, the *Rules on the Management of Grid-Connected Wind Power Generation* was enacted in 1994; the *Electricity Law* was promulgated in 1995; the *Energy Conservation Law* was issued in 1998, and the "Guidelines for Accelerating Localization of Wind Power Technology and Equipment" were issued in 2000. To ensure the construction of grid-connected wind farms, since 2002 China has adopted a franchised bidding method to implement a two-stage pricing policy within the franchised operation period; that is, implementing the price set in the bidding proposal before the wind power generating units operate for 30 000 hours. This was later changed into the comprehensive average price of the bidder, with the weight of electricity price accounting for 40 percent, which was later reduced to 25 percent. After the wind farms operate for 30 000 hours, the price follows the grid-connected average price on the market. The localization rate of wind power generating units was set at 50 percent, which was later raised to 70 percent.

The most influential of such laws and guidelines relating to renewable energy development is the "Law on Renewable Energy," which was first implemented in 2006. The law provides five systems for the development of renewable energy: the general target system, the compulsory grid-connection system, the classified pricing system, the national extra cost sharing system and the special fund system.

To ensure the implementation of this law, the Chinese Government departments devised a number of administrative decrees to match. These include: *Rules for the Trial Implementation of the Rules on the Management of Renewable Energy Price and Cost Sharing* (2006), *Rules on the Management of the Power Generation by Using Renewable Energy* (2006), *Guidelines for the Promotion of Wind Power Industry Development* (2006) *and On Strengthening the Management of Biofuel Ethanol Project Construction and Industrial Development* (2006). These rules and regulations contain specific explanations and provisions regarding the management system, the feed-in electricity price, cost sharing and the development of the renewable energy industry.

Apart from these laws and rules, China has adopted some economic incentive measures. These include the following.

*(1) Tax Concessions*

Tax concessions include low tariffs for the import of renewable energy equipment and a 50-percent reduction in the value-added tax for renewable energy production enterprises, a 6-percent value-added tax for small hydro power enterprises below the county level, import tariff and import value-added tax rebates for the import of parts and

accessories and raw materials necessary for developing and manufacturing large HP (horsepower) wind power generating units. These tax concessions need to be used to develop new products, for production and enhancement of innovative capacity, and to incorporate wind power and solar photovoltaic (PV) operation into high and new technology areas. Tax concessions are available for enterprises recognized as qualified renewable energy producers.

*(2) Interest-discount Loans*

The central government's policy mainly covers the rural areas, where interest-discount loans are primarily used for large and medium-sized biogas projects, solar energy projects and wind power technology extension. When a demonstrative project is put into operation and reaches the prescribed standards, the operators will receive a government award. Large and medium-sized renewable power projects above 3000 kW approved for construction by the state receive a 2-percent interest discount. The state also supports the industrialization of large and medium-sized power generating units. Some local governments also provide interest discount loans, small loans and tax concessions for the construction of biogas digesters in rural areas.

*(3) Subsidies*

Subsidies are mainly used in R&D, demonstrative projects and for grid-connected electricity prices. The first 50 MW wind power generating units of an enterprise receive a 600 yuan/kW subsidy, to be shared between complete unit manufacturing enterprises and enterprises producing parts and accessories. The subsidies are mainly used for R&D for new products. In 2008, the amount of subsidies doubled, increasing by 3 billion yuan, basically making up for the cost born by power grids for the connection of renewable energy power.

*(4) Direct Investment by the State.*

China's central finance department set up a special fund to support the following activities: research into the development and utilization of renewable energy; formulation of standards and demonstrative projects; renewable energy utilization projects in the rural and livestock breeding areas; building of off-grid power systems in remote areas and offshore islands; survey, assessment and related information systems concerning renewable energy sources; and the promotion of localization in the utilization and development of renewable energy equipment.

## 3. Analysis of the Current Situation of China's Renewable Energy Development and Policy Impact

China has experienced two program periods from the inception to the present. It is now implementing the program for the 11th five-year period. This section mainly analyzes the

targets realized in the two program periods and the progress of the 11th five-year development program for renewable energy and the medium-term and long-term development program for renewable energy over the past 2 years.

*(1)Rural Energy Development and Anticipation of Targets Realization*

China has made marked achievements in terms of increasing electricity services by launching such projects as *Rural Electrification*, *Bright Project* and *Electricity to the Rural Areas*. In 1995, there were 16 counties, 828 townships and 29 783 villages, including approximately 120 million people, that had no access to electricity (Shi, 1995). By the end of 2000, the number of counties without access to electricity had been reduced to 3, townships to 766 and villages to 16 509, with the number of households being reduced to 706, and the number of people to 30 million. By 2005, there was no county without electricity; the number of people without access to electricity had reduced to 20 million. By the end of 2005, 12 county towns and more than 700 townships and towns had off-grid solar PV power stations, using more than 500 000 sets of solar PV systems for household use. According to China's renewable energy development program, by 2010 the number of people without access to electricity will be reduced by another 11.50 million, and by 2015, and there will be no people without access to electricity (Shi, 2007).

People in China's rural areas mainly burn biomass, such as crop stalks, grass and firewood, for direct use in heating and cooking. This energy source is low in thermal efficiency, and creates large emissions of waste gas. In addition, it pollutes the environment and affects the health of rural women. To improve the quality of the energy used in heating and cooking, low-efficient biomass should be converted into highly-efficient clean energy. Specific methods include building biogas digesters, developing solid biomass fuel, and increasing the use of solar stoves and solar water heaters. By the end of 2006, 22 million biogas digesters, 140 000 living sewage purification biogas digesters and 2600 biogas projects had been built by large and medium-sized poultry farms, using industrial wastewater. The annual output of biogas reached approximately 9 billion $m^3$, providing quality fuel for nearly 80 million rural people. Fifty-four percent of the biogas production target of the two programs was met by 2000 and 100 percent was met by 2005. In addition, 50 percent of the target for 2010 had been met by 2006.

According to the plan, clean renewable energy will be used in 30 percent of rural homes, or approximately 40 million households (approximately 160 million people) will use biogas for cooking and lighting by 2010). Clean renewable energy will be used in 70 percent of rural homes by 2020, equivalent to approximately 80 million households (approximately

300 million people).

Currently, less than 10 percent of the rural people use quality fuel for cooking and heating. However, the current production of biogas and the development trends show that it is entirely feasible that these targets will be realized by 2010 and 2020. First, rural energy supply technologies, associated with, for example, biogas, off-grid wind power and solar PV, have matured and are easy to command. Domestic enterprises can produce the technical equipment needed. Second, the projects need only small amounts of investment and the funds are readily available from secure sources, including central and local finances.

*(2) Targets and Implementation Schedule for Improving Energy Structure and Obstacles on the Way*

China has set the target of bringing the proportion of renewable energy in total energy consumption up to 10 percent by 2010 and up to 15 percent by 2020. This will be realized mainly by developing hydro power. In 2006, China's renewable energy was converted to 199.439 million tons of standard coal, accounting for 8.1 percent of the total energy consumption in the same year. Of this, hydropower was converted to 148.20 million tons of standard coal, accounting for 97 percent of total renewable energy. Given these figures, China realizing its goal for 2010 should not be a problem.

China has to improve its energy structure by rapidly developing renewable energy, because fossil fuel consumption is also increasing steadily. According to the renewable energy development programs, China's renewable energy consumption will reach 300 million tons of standard coal by 2010 and 600 million tons of standard coal by 2020. In the same period, the total energy consumption is expected to reach 3 billion tons of standard coal and 4 billion tons of standard coal, respectively.Fossil fuel consumption in the form of standard coal is expected to increase by 700 million tons. For instance, renewable energy accounted for approximately 15 percent of the primary energy consumption in 2005 and this proportion dropped to 8.1 percent in 2006. This is due to the faster growth of fossil fuel consumption. After 2030, China will have to rely on non-hydro power to improve its energy structure, because the exploitable water power will be exhausted. There are two main problems relating hydropower development. One is that the building of large hydropower stations involves displacement of people and is associated with considerable environmental impact. This has been especially apparent in recent years, when the pace of large hydropower station building has slowed down due to, for example, difficulty in the relocation of displaced people and in consideration of environmental impacts. The second is that the technical equipment for small hydropower stations is outdated and follow-up technical service and maintenance are lacking, leading to stoppage after a few years of operation.

**Table 2. China's Ranking in the World in Terms of Renewable Energy Development Scale**

| Renewable energy | Size | World ranking |
|---|---|---|
| Hydropower (billion kW ) | 4829 | 1 |
| Liquid fuels (tons, oil equipment) | 1043 | 3 |
| Wind power installed capacity (MW) | 5875 | 5 |
| Concentrating solar thermal power area (million $m^2$) | 100 | 1 |
| Solar PVcapacity (kW) | 80 000 | 4 |
| Biopower (billion kWh) | 6.39 | 21 |

Sources: Based on "China's PV Development Report 2007," BP statistics review and EIA international data.

Note: PV, photovoltaic.

China is also in the forefront in terms of the development of large-scale non-hydro-power. It ranks first in the utilization of solar heat, fourth in solar PV and fifth in wind power (see Table 2). However, its fossil fuels still account for over 90 percent of total energy consumption. If fossil fuels are to be replaced, renewable energy must be produced on a large scale. That requires the power generated by wind, solar PV and biomass to be connected to power grids and the replacement of fossil fuels with liquid biofuel. However, there are some problems in this regard that affect the development of power generation by renewable sources.

In 2000–2005, generation of non-hydro renewable energy grew by 52.4 percent in the world. In China, it grew by only 3.5 percent. The proportion of power generated by renewable sources other than hydro of total power generation was less than 1 percent, even less in 2005 than in 2000. China's power output accounted for over 13 percent in 2005, but the power generated by renewable sources other than hydro was less than 1 percent.

China's geothermal power development has remained stagnant due to insufficient access to subterranean water. Therefore, China has lagged behind other countries. China has developed solar PV mainly in remote areas, with development speed also lagging behind many developed countries. China is ranked fourth in the world in terms of the development of ethanol fuel production, lagging far behind the world's first two countries: USA and Brazil. China has also lagged far behind Germany, Spain, Korea and Great Britain in the growth of cumulative wind power installed capacity.

According to the statistics from the China Wind Power Association, the cumulative wind power installed capacity at the end of 2007 was 5875 MW, meeting the target set by the state 3 years ahead of schedule. China has built more than 100 wind farms, with more than 350 000 small off-grid turbines in remote areas. However, the growth in

installed capacity does not necessarily result in the growth of wind power output. Some wind power turbines have stayed non-operative due to electricity prices and wind farm design. The grid-connected wind power installed capacity was 2 593 300 kW in 2006, with approximately 3.8 billion kWh of electricity accessing the power grid, operating for for 1465 hours a year, which was much less than the designed 2000 hours and above. Of the 1.26 million kW of wind power installed capacity at the end of 2005, at least 25 000 kW did not generate any electricity due to problems with turbines (Wang and Li, 2008).

In 2006, China's biomass power installed capacity was approximately 2.24 million kW and the electricity generated was approximately 6.39 billion kWh. However, the annual operating hours were only 2853. The reason is that each individual project was so big that the raw material supply within the reasonable transport radius became inadequate. Of all the renewable energy sources except hydro power, liquid biomass fuel has developed the fastest, experiencing a leapfrog development from the very start in 2003 until it reached its peak in 2005. However, with the control of the government, the development speed dropped significantly. The main reason for this was that the production of liquid biomass fuel using grain as raw materials had caused strained supply and price rises of grain. The development of liquid fuel using would also demand the expansion of land areas, which would also affect the grain sowing areas. China has to follow a path that will not reduce the grain sowing areas. However, how much land can China use for planting forests for use in producing liquid fuel? There has still not been a reasonable assessment of and scientific planning concerning such utilization of land.

China's use of solar energy has grown steadily, contributing to the replacement of fossil fuels. In 2006, solar hot water heaters generated 90 million $m^3$, equivalent to 36 million tons of standard coal. However, solar water heaters are used only to replace energy used for cooking and heating, accounting for only about 10 percent of total energy consumption. Due to space limitations, some cities ban the installation of solar water heaters. That means that the demand for solar water heaters is stimulated only by people living in county towns or rural areas, whose incomes are low and for whom energy consumption is only about half that in cities. This will affect the future market for solar water heaters. In addition, the development of solar water heaters lacks policy support.

## 4. China's Renewable Energy Industry and Its Problems

China's solar water heater producers are mainly non-governmental. Although without special policy support, the production system is still fairly complete in comparison to

other renewable energy producers. The main reason is that it has its own intellectual property rights and production technology. Production is based on market competition and, therefore, costs are low, and are acceptable to domestic consumers. A solar water heater in China costs approximately US$100 per square meter, 10–15 percent of the price in Europe.

China's solar PV industry has gained much ground. However, the industry differs from the solar water heater industry. Solar PV market is not domestic in China but is in developed countries. The main reason is that the feed-in price of solar PV power is more than 10-fold that generated by coal, which is very difficult for the home market to accept. China does not have a full command of solar power class silicon production technology. The strained supply of raw materials has made the silicon price rise 2–2.5 times that at home. It is hard to lower the cost of solar PV power. At present, the cost of the polycrystalline silicon materials in the front-end of the solar energy cell industrial chain accounts for 70 percent of the whole solar power system. The development of PV in developed countries has stimulated the development of the solar PV industry. China has become a PV cell processing and assembling base because of its comparative advantage in labor. Its production capacities in the production of high-purity silicon materials, silicon ingots, silicon wafers, silicon cells and components have reached 25, 580, 500, 1400 and 1087 MW, respectively, ranking third in the world. However, China's market demand is seriously lagging and it has to export 96 percent of PV products.

The above discussion shows that economic globalization has enabled China to be part of the global industry but it cannot change the ability of consumption of China. Only when the products and equipment provided by the renewable energy industry are well matched with what the market in China can take in, will it be possible to improve the energy structure of China. At present, Chinese polycrystalline silicon-producing enterprises usually use the improved Siemens process, which requires approximately 10 kg of polycrystalline silicon and 5800–6000 kWh of electricity consumption to produce a 1 kW solar cell.

China's solar PV is mainly used in off-grid rural areas, telecom and industrial applications, which accounted for 41.3 and 33.8 percent of the total solar PV installed capacity by 2006. The grid-connected capacity accounts for only 5.1 percent of the solar PV market. The solar PV power systems in rural areas operate mainly by relying on government subsidies. Such market structure has, to a certain extent, restricted the development of the solar PV power market.

China's wind power industry entered into a growth stage in 2003. Its development is now set to scale up. The expansion of the wind power market has given a direct impetus to the wind power industry. By the end of 2007, there were more than 40 wind turbine and

parts producers, raising the turbine manufacturing capacity. China has in fact become the world's largest small wind power generator manufacturer and market (CEIA, 2007).

According to statistics from the China Wind Power Association, in 2004, Chinese enterprises claimed an 18 percent share of the total market on the Chinese mainland, and foreign enterprises 82 percent, comprising mostly enterprises from Demark, Germany and Spain. However, great changes took place in 2006, when the market shares of domestic enterprises rose to 41.3 percent and those of foreign capital enterprises dropped to 55.1 percent, with the rest occupied by joint ventures. The market share change is mainly attributable to the strict mandate on the proportion of localization of wind farm equipment, which should reach over 70 percent. However, China has made major breakthroughs in the manufacturing technology of wind power generators. Still, China is lagging behind and market demand has to be met through imports. At present, the mainstream wind power installed capacity is less than 850 kW, which accounted for 79 percent of the total installed capacity in 2006. The low HP of power generators is an important factor relating to the low cost of wind power development.

The declining cost of wind power with technical progress has made it the most competitive renewable energy source. The International Energy Agency reported that in 1980, the cost of wind power was 80 cents per kWh. However, it dropped to only 10 cents per kWh by 1991. Now, the best offshore wind farm production cost has dropped to 3–4 cents per kWh, and is 6–9 cents at most (not including subsidies), which is close to the cost of coal power generation. In 2007, global investment in the renewable energy equipment production increased by 30 percent, reaching US$71bn, of which 48 percent was used in wind farm construction.

China has introduced a franchised bidding system in wind farm construction, which requires a standard for market access. Only bid winners have access to the wind power industry. In order to occupy the market, Chinese state-affiliated power enterprises all try to bid at low prices. This, plus the demand for localization of domestic equipment, has given rise to a pattern of the wind power industry having state-owned enterprises as the main players. The low efficiency and lack of risk resistance on the part of state-owned enterprises will ultimately affect the efficiency of the development of the wind power industry and slow down the drop in cost brought about by technical progress.

## III. Conclusions and Recommendations

China has achieved tremendous success in its policy of stimulating rural energy construction and easing the problem of rural areas lacking access to electricity and other forms of

energy.

China will face several problems in replacing fossil fuel with renewable energy and in developing its renewable energy industry. China's market is limited in its capacity to bear the differentials between high-priced renewable energy and relatively cheaper fossil fuels. In addition, the replacement of fossil fuels means that renewable energy must enter the energy market through the market mechanism. This requires the market-oriented development of the renewable energy industry, and the imperfection of the market mechanism will affect the development of the renewable energy industry to a certain extent.

China's policy measures concerning the development of renewable energy can be placed into the following four categories: (i) basic work such as R&D, pilot projects, resources assessment and technical standards; (ii) rural energy plant construction to ease energy supply in rural and remote areas; (iii) expand and ensure the market shares of renewable energy on the current energy market; and (iv) stimulate technical progress and the building of the industrial system. What is lacking here is policy considering the market mechanism. Both renewable energy production enterprises and government overstress the role of the government in the development of renewable energy. State-owned enterprises deem that they need government support to dispense with the full consideration of market risks; the government deems that renewable energy has externalities and social benefits and, therefore, interferes in prices and taxation without regard for the role of the competitive market.

China's renewable energy policy is interest-driven, which means that renewable energy development is stimulated by offering subsidies and concessions in prices and taxes. However, the interest-driven policy is built on the market mechanism. Without a perfect market, these policies will be greatly discounted in their impact.

Technical innovation and industrialization in the area of renewable energy are important means of lowering costs. China is in for a period of high-speed development of its economy and the rising demand for energy is irreversible. If the technical progress and speed of development of renewable energy lags behind the growth in demand, it is will be hard to realize the improvement of its energy structure. Improvement in energy structure will benefit not only China but also the world as a whole. It is necessary for developed countries to transfer at low prices relevant technologies to China, and China should make more investments in R&D of renewable energy technology so as to realize industrialization of new technologies as soon as possible and to lower the cost of renewable energy.

There is a certain measure of blindness in the development of China's renewable energy. A resources survey has not been undertaken. It stresses growth in installed capacity but neglects grid-connected power generation. Besides, China has not taken into full

consideration the national conditions in developing renewable energy sources. At present, China's solar PV development is not well matched with the domestic market demand, resulting in the overgrowth of the output value of the renewable energy industry and limited utilization. What China is lacking in changing its energy structure is time. China should not prioritize those renewable energy sources for which costs cannot be lowered in a short period of time.

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