Synopsis

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Bioenergy: Future Direction of China's Energy and Environment Integrated Strategy?

With the rapid growth of China's economy since the 1990s, its energy demand is increasing at an accelerating rate. There is no doubt that the rapidly growing energy demand in China will profoundly impact the world energy market. What really is the current status of China's energy? How serious is the energy shortage? What strategies and approaches should be undertaken to overcome the serious energy shortage in order to ensure the sustainable development of China's economy and society? Two key related events took place in 2005 and 2007. One is that the "Kyoto Protocol" took effect in 2005, impelling China to rearrange its energy use in order to reduce greenhouse gas emission in the future, and the other is that the "Chinese Renewable Energy Law" was ratified by the National People's Congress (NPC). This law puts the use of renewable energy resources on the primary pathway. Besides petroleum, biomass energy is considered a critical alternative in China's energy consumption and new rural construction campaign in 2007.

Current Status of Chinese Energy Use and Environmental Pollution

Since 1993, the imported crude oil in China has dramatically increased, with 30, 70, and 100 million tons in 1993, 2000, and 2003, respectively (Fig. 1). The imported crude oil reached 120 million tons by 2004, which accounted for about 40% total oil consumption (1, 2). A deficit of 100 million t of petroleum and 4000 million m^3 of natural gas is anticipated by 2010 (3). With the proposed long-term goal of further development by 2020, the gross domestic production (GDP) is projected to reach USD 5000×10^9. Energy demand should reach 2.5–3.3 thousand million tons of standard coal, and the petroleum shortage is estimated to be 160–220 million t (3). The average petroleum storage *per capita* is only 10% of the world's average level, and coal storage *per capita* is only half of the world's average level (4).

Large energy consumption and low use efficiency cause severe environmental pollution in China (5). Based on air quality monitoring statistics in 2003, two thirds of Chinese cities are below the second class of the national air quality standard, of which 137 cities are below the third class, accounting for 40.5% of the monitored cities. Vehicle gas emission (VGE) is the major cause of atmospheric pollution in urban area. The statistics showed that VGE in large- and medium-sized cities has reached the emission load by 50%. Some even reached 90%. The amount of SO_2 emission in China is now the most in the world, and CO_2 ranks second. In 1998, 20.9 million t was emitted, 85% of which were contributed by coal combustion. One third of the China's territory is polluted by acid rain, which is estimated to cause GDP reduction by 2%. Greenhouse gas emission has become a major contributor to climate change in China. It is predicted that the climate in China will continue to become warmer and the nationwide average air temperature will rise 1.7°C by 2020–2030, and 2.2°C by 2050 (6–8).

The most important current social concerns in China are the so-called "three agro-problems," i.e., social and economic issues related to agriculture, rural area development, and farmers. Resolving these problems has much to do with the potential use of biomass energy. Nearly

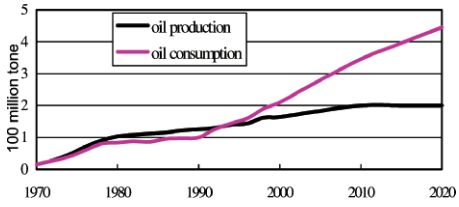

Figure 1. Temporal changes and trajectories of oil production and consumption in China.

900 million people now live in rural areas of China, accounting for over 70% of the total population. About 100 million of them do not have access to electricity, and their energy source mainly comes from firewood and straw (9). The amount of collected firewood has exceeded 15% of the appropriate harvest yield, resulting in extensive deforestation and severe soil and water erosion. Traditional ways of using firewood and straw for cooking and heating have very low energy transformation efficiency (<10%). Soot dust emission from firewood and straw combustion can further pollute farmer's living environments and cause many health problems (10). It is estimated that 200 million t of straw were *in situ* combusted every year, and 25 million tons of domestic animal feces were abandoned without any treatment. Together with other pollution sources, environmental pollution caused 75% of degraded farmland that has very low productivity. Besides the impact of severe environmental pollution, low profit-bearing agro-products, low income of farmers, and excessive labor forces largely hinder China's agricultural development. If half of the biomass resources were used appropriately, the benefits from biomass energy use could reach nearly USD 120 thousand million. Furthermore, if advanced biomass combustion techniques were used, the energy transformation efficiency could be improved by 35–40%. Using biomass energy efficiently could transform the traditional primary agricultural production to industrialized agricultural production and might further create "the third battle field" for enhancing the profit of agro-products and increasing farmers' incomes. Therefore, developing and extending biomass fuel, especially plant-based biomass fuel through afforestation planting energy-source type crops (11–14), and establishing energy-source oriented agriculture and forestry industry would greatly enhance China's agricultural economy, improve agricultural productivity, adjust industrialized agricultural structure, form new economic growth hotspots, and increase job opportunities and farmers' income. Agricultural economic improvements may further facilitate the maintenance of ecological balance, alleviate of soil and water erosion, and conserve biodiversity.

Compared with developed countries, the degree of dependence of China's economic and social development on energy is much more profound. For example, the total expenditure on energy consumption was USD 160 thousand million US in 2001 in China, accounting for 13% of the total national GDP, whereas the corresponding figure in the United States was only 7%. The energy consumption rate per unit product averaged from eight high energy consuming industries of China is 47% higher than that in developed countries. The total amount of energy consumption in these eight industries accounts for 73% of the total energy consumed by all the industry departments (3). With emphasis on industrial energy saving, enhancing energy saving status in other areas, such as construction and transportation, is also very important. Energy consumed by the construction industry accounts for 47% of China's total energy consumption. If environmentally friendly energy saving techniques were extensively applied, half of the energy consumed by the construction industry could be saved. With car sales continuing to top the annual sale mark of 5 million cars set in 2004, the car industry is facing even more difficult challenges on energy saving. Extensive use of ethanol gasoline is considered to be an effective substitute for petroleum gasoline to improve environmental quality and to save energy.

Bioenergy Resources in China

China has rich biodiversity, with 30 thousand high plant species (15) and 200×10^9 t of biomass production per year (16), which is equal to 2×10^9 t of petroleum and about three times the current one-time-consumed energy. China has diverse oil plants—over 800 of them have oil content of 10% or more, and over 100 are petroleum plants. Some oil plants have very high oil content but are less abundant, such as *Litsea subcoriacea* and *Lindera,* which produce seeds with oil content of 64.4% and 67.2%, respectively. Some not only have very high oil content but also are very abundant, such as *Artemisia monosperma* and *Artemisia ordosica,* which are mainly distributed in Northwestern China, with seed oil content of 16–23% and total storage of 500 thousand tons (17). China also has over 2000 types of wild and cultivated firewood plants. Some of them are introduced species. For example, there are over 60 introduced Eucalyptus tree species in China. Most (ca. 75%) plant species grown for fuel are distributed in south China and the rest mainly in temperate areas of China. In south China, most plant species grown for fuel grow in very limited areas because of their limited benefits (18).

Current Status and Future Development of Bioenergy in China

Commercialized biomass energy only accounts for 0.5% of the total one-time-consumed energy (19) and about 14% of the total energy consumed in China (18, 20). Based on the report *Technical Assessment on Bioenergy Utilization in China* by the World Natural Foundation in 2003 (21), China has very abundant bioenergy resources, but these resources have very low use efficiency. Bioenergy is mainly used in rural areas, accounting for 70% of rural energy consumption. Firewood plantations were initially planted in 1981. By 1995, firewood plantation area reached 4.95 million ha, providing 20–25 million tons of firewood each year that largely alleviated the rural energy crisis. At present, there are 210 million m^3 of firewood produced every year, with a heat value of 15 MJ kg^{-1}, which is equivalent to 120 million t of standard coal (22). There are 620 million t of straw produced each year, but only 25–30% of it is used as fuel, and that is equivalent to about 0.75 million t of standard coal. There are 2100 million cubic meters of firedamp produced each year, equivalent to 7 million t of standard coal (23).

Future Energy Plans

The rapidly growing economy and profoundly changing society of China largely depends upon energy availability. Biomass energy is considered to be a clean energy resource because the amount of contaminant materials is only 10% of that in coal. Furthermore, biological CO_2 emission and absorption are natural processes of carbon cycling. Therefore, expanding the use of biomass energy could be one of the most important approaches for attenuating CO_2 emission. In an effort to deal with environment pollution and energy crisis, China has put forward a strategic framework for energy development for the next 20 y (24). In this framework, energy saving is considered to be the top priority, and other strategies include adjustment of energy use structure, use of environmentally friendly energy, and reduction of dependency on imported oil to below 55%. Major pollutants would be attenuated by 46–60% from their current status. Biomass energy would become the major component in the future sustainable energy system and is expected to account for 40% or more of the total energy consumption by the middle of this century.

Energy saving and constantly searching for new energy sources is of paramount importance to China's ongoing economic reform and industrial structure adjustment. Since 1959, researchers have conducted several field surveys on the distribution of wild plant species grown for fuel and lots of studies on domestication of introduced species. Research facilities are being established to breed and select high-quality seed sources targeting these plants, including both natural energy woody plants and common crops. Scientists are also developing more efficient bioenergy use techniques, for example, making ethanol from cellulose and biodiesel oil production. These research efforts provide valuable scientific and technological information for better use of energy plants.

In order to avoid food security problems, the bioenergy industry should avoid placing grain in competition with people, and land in competition with agriculture. The bioenergy industry should mitigate conflict between energy and the environment and promote economic recycling.

In short, although China has a large amount of bioenergy storage, many factors may constrain effective use and exploitation of bioenergy at the present time, including *i)* limited techniques for selection and cultivation of energy plants, *ii)* low bioenergy use efficiency, *iii)* difficulties in collection of bioenergy materials due to widely scattered distribution, *iv)* limited and costly facilities for bioenergy production, *v)* lack of basic scientific information and technical support, *vi)* lack of regional planning on bioenergy development and associated supportive policies, and *vii)* low economic interest and lack of public awareness. To overcome these problems, China has formed its bioenergy development strategy (5) and 2006–2015 science and technology planning (7), emphasizing extension of mature technology and advanced bioenergy producing facilities, establishment of the bioenergy industry, and exploitation of bioenergy resources. These new developments include energy agriculture and forestry, reduction of manufacture costs on hydrogen energy, compound oil, and celluloethanol through technological innovation, speeding up energy market reforms through improvement of law and policy system, subsidization or tax deduction on renewable energy products, and finally enhancement of public consciousness on the use of renewable energy resources.

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