

RESEARCH ON CHINESE HOUSEHOLD PRACTICAL ENERGY TECHNOLOGIES

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Abstract

Chinese household energy consumption is growing fast with the steady rapid growth of economy, the constant increasing residents' income and the promotion of urbanization process. China has been actively developing and introducing the household energy practical technologies, which not only improves the energy efficiency and renewable energy utilization, but also reduces the household energy consumption. Meanwhile, the residents' life quality keeps rising. Firstly, this paper introduces the present situation of the development of Chinese household practical energy technologies--solar energy utilization technologies including solar water heater, solar energy lighting (PV), and solar stoves, and green lighting technologies like energy saving lamps (CFL). Then it further studies the working principles, applicable conditions, the status quo and problems in China of the typical household energy practical technologies: Finally, it makes some suggestions such as strengthening the policy support in household energy practical technology, fully utilizing international mechanism, for example, CDM or other market mechanisms, enlarging the financing channel for household energy practical technologies promotion, and deepening the international cooperation in the field of household energy practical technology.

1 Introduction

Ever since the reform and opening-up, energy consumption in China is growing fast with the steady rapid growth of economy, the constant increasing residents' income, and the promotion of urbanization process^[1]. However, according to the energy consumption structure, the growth speed of residents' household energy consumption is far lower than that of the total energy consumption, and the ratio is of downward trend. From 1980 to 2005, the total energy consumption rose from 602.75 to 2,233.19 million ton of standard coal, with average annual increasing rate of 5.38%, and annual increasing rate per capita of 4.19%; meanwhile, residents' household energy consumption from 110.15 to 233.93 million tons of standard coal, with average annual increasing rate per capita of 2.46%, and the ratio of residents' energy consumption in total energy consumption has decreased from 18.3% to 10.5%. That mainly lies in two reasons, first, industrialization and urbanization are

developing fast in China, especially in heavy industrialization, and the increasing rate of industry and traffic energy consumption is faster than that of residents' energy consumption; secondly, China has been actively developing and introducing the household energy practical technologies, which not only improves the energy efficiency and renewable energy utilization, but also reduces the household energy consumption. Meanwhile, the residents' life quality keeps rising^[2].

China is a country with relatively scarcity of energy resource, therefore it is of significant importance for energy safety, environmental protection and climate change to improve energy efficiency and develop renewable energy^[3]. Chinese government has emphasized the importance of developing and disseminating practical energy technologies, supported industrial / financial / tax policies making, and achieved remarkable effects. The technologies include:

Firstly, solar energy utilization technologies. Solar energy low-temperature heat utilization technologies include: solar green house, solar stove, passive solar house, solar heater and solar dryer, etc. Currently, the most popular promotion is rural solar furnace, domestic solar heater. Besides, in remote areas which are lack of electricity, small scale solar photo-electric technologies such as energy photovoltaic power generation and lighting (for roads) are applied. Secondly, green lighting technologies. Promote green lighting technology and product, including light source, lamps and ballast, as well as high-efficiency fluorescent lamps such as lanthanide energy-saving lamps. Replace the ordinary incandescent lamps with compact fluorescent lamps, or T5/T8 fluorescent lamps inside constructions. Utilize metal halide lamp and high pressure sodium lamp on the sides of roads and spacious places, and develop urban landscape LED lamps floodlighting.

These technologies are easy, convenient and of low cost, which is good for promotion^[4]. Main typical such kind of technologies are reviewed in the following sections.

2 Solar water heater

2.1 Working principles of solar water heater

Solar water heater is a thermal energy device which utilizes solar energy to heat water from low temperature to high

temperature. From Figure 1 we can see that, vacuum tube solar water heater is composed of all-glass vacuum collector tube, storage tank, braces and relevant spare parts, among which all-glass vacuum collector tube is in charge of turning solar energy into heat energy. The side of the collector tube that exposed to sunlight has a higher temperature, while the other side has lower temperature; hence water in the tube is of temperature difference. Based on the principle of hot water floating upward while cold water downward, there is water micro-circulation which produces needed hot water. The systems are composed of collector, insulation water tank and connecting tubes [5].

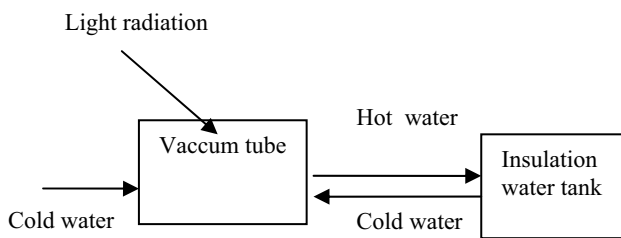


Figure 1: Working principles of solar water heater.

Solar collector per m^2 can produce heat equivalent to $2.5KWh/(m^2 \cdot day)$ in normal conditions. This number means saving 250kg standard coal every year, and more than 700kg CO_2 equivalent emission can be reduced. Solar water heater can be widely applied to household hot water, heating, and air conditioning etc, which is of good economic and environmental benefits [6].

2.2 Applicable conditions for solar water heater

Solar water heater has a wide range of applications. Any places with sunshine and clean water source (tap water) can install solar water heater. In China, solar water heater that reaches quality standards should be of anti-freezing, anti-corrosion, wind/hail/rain/snow-resistant functions, so as to apply in winter or in high latitude areas, and suitable for outdoor utilization in poor environmental conditions. The connection approach of solar water heater is plug in connection, main technical specifications: maximum working current 16A, maximum withstanding voltage 1000V, applied temperature $-40 \sim 90 \text{ }^\circ\text{C}$, maximum working humidity 5%-95% (no coagulation), water-proof level IP65. Solar water heater can be applied not only in household, but also in public buildings such as hotels, restaurants, schools, office organizations [7].

2.3 Application status quo and problems of solar water heater in China

Currently, solar water heater is the most widely applied, solar product with fastest industrialization, which is widely applied around China with more than 30 million households as clients, which takes up almost 60% of the global equipments. According to the Mid and long-term plan of renewable energy development made by State Council, the maintenance of solar

water heater will reach 150,000,000 m^2 in 2010, and 300,000,000 m^2 by 2020, that is to replace 22.50 million ton of standard coal, or to save 70 billion KWh electricity. The saved energy consumption is expected to take up 3.9% and 7.2% of the total national energy consumption in 2010 and 2020 respectively. At present, the major problems in solar water heater applications are:

It is relatively more expensive than gas heater and electricity heater, and initial investment is big and especially hard to promote in rural areas. One solar water heater with good quality is about 3000 yuan, which is difficult for low-income household to bear [8].

The industry of solar water heater is not developed maturely yet, and companies are of low self-discipline. The differences among factories are big, thus lots of products with low quality after sale service are in the market, which harms customers' rights.

The industry is of low conformable degree, and general quality is not high and stable, especially small and medium sized companies. The product has a certain gap between gas heater/electricity heater in the areas of reliability, durability and convenience, which influenced the promotion of solar water heater.

3 Solar energy lighting (PV)

3.1 Working principle of photovoltaic lighting system

Photovoltaic lighting system is a photoelectric conversion system, which is called "silicon wafers ground PV modules" in specialized field. The working principle is to utilize silicon wafers to receive sunlight and convert it into electricity, and then store it in storage battery, and then controlled by photoreceptor switch, so that when it is dark, the light is on, and when it is bright, the light is off. PV is an application product of photoelectric conversion technology, which is energy-saving, environmental friendly, no need of wires, automatic control and change locations anytime. Photovoltaic lighting system is divided into: yard lamp, road lamp, solar insecticidal lamp, and architectural lamp etc [9]. The system is composed of:

Crystalline silicon solar cell panel: Solar cell panel is the core of the whole system, which convert sunlight into direct current, and store it in storage battery for lighting during night.

Solar energy controller: Controller is the device to control and manage Photovoltaic lighting system. Because there are many approaches for controller to control, so the requirements for controller in actual application are not the same, therefore the controller product requirements are not the same.

Storage battery: Include lead-acid storage battery and colloidal storage battery. The biggest difference between these two is that colloidal battery has more straighter

discharge curve than the traditional lead-acid battery, and also the lifetime of the former is about one time longer than that of the latter, plus colloidal battery has better high/low temperature resistance^[10].

Light source: Light source is the illuminant at night, usually use electronic energy saving lamp, high pressure sodium lamp, low pressure sodium lamp, and LED lamp etc., based on different locations and utilizations.

3.2 Applicable conditions of solar energy lighting

Theoretically speaking, exposed situations with sunlight can install photovoltaic lighting systems. However, under current circumstances, areas with longer sunshine are more suitable for photovoltaic lighting system promotion, while areas with shorter sunshine time and more rainy days are hard to achieve solar lighting so far.

3.3 Application status quo and problems of solar energy lighting in China

China started late in solar industry, but development speed is fast. Since 2004, the increasing rate of solar industry is above 30%. Recent years, solar lamps have entered into daily lighting program. Road lamps, yard lamps, turf lamps, landscape lamps, and craft lamps are applied widely. The major problems are:

Relatively low technology: The production amount of solar battery panel of China is the first all over the world, yet because of lacking of core technologies, there are very few companies that can produce single crystal silicon and polysilicon by themselves; there are no industrial standards for solar lighting; spare parts are limited, with different lifetime; energy consumption for production is very high; the recovery problem of storage battery etc^[11].

Not only of high price, but also restricted by many natural factors. Currently, solar road lamp development is restricted by high price, high initial investment, and natural elements such as sunlight, weathers, etc.

4 Solar stoves

4.1 Working principles of solar stoves

Solar stove is a device to gather solar energy for cooking and hot water supply. The function of solar stove is to accumulate the low-density and dispersed solar radiation energy for cooking. According to the different natural conditions and life habits, the actual application time of solar stove is 400-600h/year. Each stove can save 500-800kg of crop residue/year, which is of significant economic and ecological benefits. Currently, solar stoves that are promoted include box-type solar stove and light concentration solar stove:

Box-type solar stove is a box with only one light transmission side, and the rest sides are made from thermal insulating materials. It is simple, cheap and convenient. The temperature of box-style solar stove is lower than 200 °C, which can be applied for cooking such as making steamed bread, rice, stewed meat etc^[12].

Light concentration solar stove utilized the characteristics of light concentration characteristics of parabolic surface, which raise the efficiency and concentration tremendously. The temperature at the bottom of the stove can reach 500 °C, which can be applied in frying/cooking, and hot water supply. But it is of complex structure, and relatively higher cost.

4.2 Applicable conditions for solar stoves

Application of solar stoves should meet two conditions, firstly, long sunshine time, high sunshine intensity. So far, the areas which the solar stoves applied are western provinces with annual sunshine time above 2800 hours such as Ningxia, Gansu, Qinghai etc., and it is hard to promote in short sunshine areas; secondly, fine weather is needed, because solar stove can not be used when it is cloudy, rainy, snowy or windy.

4.3 Application status quo and problems of solar stove in China

The research and promotion of solar stoves in China has been more than 20 years. From dispersed exploration experiments to organized national joint research, from test/pilot to large scale production and promotion, from national subsidiary for promotion to half commercialized then totally commercialized sale, technology and application of solar stove have achieved huge progress in the areas of design theory, material processing, technical standard, industrialization production, promotion sales, and after sale service. In recent years, the promotion and application of solar stove increase quickly, the market maintenance of solar stove was around 332,000 in 2000, and now the number is 800,000. It is estimated that the number will still increase fast in the near future^[13]. The major problems are:

Low popularization rate. There is a big potential to promote solar stove in western countryside of China, but so far the popularization rate is relatively low, and there is sign of slowing down recently.

Factories are at uneven levels, with unstable technologies and lack of relevant maintenance service.

Central and local governments are lack of unified planning, less investment, lack of encouraging policies, and not enough propaganda.

5 Energy saving lamps (CFL)

5.1 The working principles of energy saving lamps (CFL)

There are many types of energy-saving lamps, and here we are talking about compact fluorescence lamp (CFL). It is composed of energy-saving lamps, PCB panel, plastic shell, lamp cap and packaging. It is energy saving as compared with ordinary incandescent lamp, and it has a quite different working principle^[14]. Ordinary incandescent lamp has 10 lumen/watt of light efficiency, the working principle is when lamp is connected into a circuit, current passes through the lamp wire, causes the heat effect which enables the lamp to emit visible light and infrared light. The phenomenon is visible when temperature is raised to 700K, but because wire is working under very high working temperature, most of the energy is wasted in the form of infrared light, and because of the high evaporation speed, wire has a short lifetime, which is about 1000 hours. Working principle of energy saving lamp (CFL) is to heat wire through ballast, and at the temperature of around 1160K, wires start to emit electrons (because electron powder were painted on surface of wire). When electron meets argon atom, non-elastic collision occurs; after getting energy from the collision, argon atom collides with mercury atom, which passes energy to mercury atom; this leads to transition of mercury atom which results in ionization, and emit ultra-violet (UV) light with wavelength of 253.7nm, the UV light in turn excites the fluorescence powder luminescence. The working temperature of fluorescence lamp wire is 1160K or so, which is much lower than the temperature of 2200-2700K of incandescent lamp. Therefore, its lifetime has increased to above 5000 hours. And since there is no current heat effect, fluorescence powder has a high energy conversion efficiency, light efficiency is more than 50 lumen/watt.

Compared with ordinary lamps, energy-saving lamps are of high light efficiency and energy saving. For example, a 7W H-type energy saving lamp has the same luminous flux as 40W ordinary incandescent lamp; a 9W H-type energy saving lamp has the same luminous flux as 60W ordinary incandescent lamp; Efficiency has risen 5-6 times, and is 30% higher than the ordinary straight tube model.

5.2 The applicable conditions of energy saving lamp (CFL)

There is no difference between energy saving lamp (CFL) and ordinary lamp, which means any places with lamps can be replaced with energy saving lamp. China is big producer of energy saving lamps. According to statistics, from 1997 to 2006, the production amount of energy saving lamps raised from 0.2 billion to 2.4 billion, which is 12 times of increase. Energy saving lamps has also taken up a higher and higher ratio in light source^[15]. In 1999, the ratio was only 6.34%, while in 2005, it reached to 17.64%, which increased 11 percentage. In 2005, there are 103 companies for energy saving lamps production, among which there are 7 companies that produces more than 50 million lamps, and 26 companies produce more than 20 million. The total number of lamps

produced by these 26 companies takes up 78% of the national energy saving production, famous producers are:

5.3 Application status quo and problems of light saving lamp (CFL) in China

China has emphasized a lot on the work of energy saving lamps promotion. Since 1996, organized and implemented China green lighting project, and listed it into energy saving areas of "9th 5-year plan"/"10th 5-year plan" and energy saving projects of "11th 5-year plan". According the energy saving and emission reduction working plan and 10 important energy saving projects implementation suggestion issued by the State Council, China has promoted high efficiency lighting product 0.15 billion pieces, saving electricity 29 billion KWh (saving 15 million ton of coal for power generation, and reduce CO² discharges by 29 million ton, SO₂ discharges by 0.29 million ton). Meanwhile, Chinese government will cooperate with UNDP and GEF on "gradually eliminating incandescent lamp, and accelerating the process of energy saving lamps promotion" program, to support the factories producing incandescent lamps converting to energy saving lamps. After decades of hard work and development, energy saving lamps industry in China has been developing fast and achieved tremendously. The quantity, quality of such lamps and the export has experienced unprecedented development and increase. 85% of the world's energy saving lamps are coming from China. Although China is the biggest energy-saving lamps producer and consumer all over the world, yet the promotion is not idealistic, and it takes up less than 20% of the household utilization. The main reasons are the followings:

Consumers don't understand energy saving lamps, and the different between such lamps with ordinary incandescent lamps, therefore unable to make right decisions.

Price is high. Take CFL for example, the price of CFL is usually several times or even dozens times of the ordinary lamp, which discourage customers to use.

Market has not standardized yet, and some goods are of poor quality, which can not generate the effects of energy saving, therefore passes the false information to potential energy saving lamp buyers, to make them change their decisions.

6 Conclusions and suggestions

From the analysis of 5 types of typical household energy practical technology, we can conclude and make following suggestions:

Firstly, China has comprehended lots of energy saving and new energy practical technology over many years of R&D, demonstration and promotion practice. These technologies are simple and practical, cheap, adaptable, easy to promote, and industrial system and service system matched with these technologies have preliminary formed. The promotion of these technologies is beneficial to local habitants in high-

quality energy supply, energy saving, biological and environmental protection, green house gas emission reduction, and with good economy, social and environmental benefits.

Secondly, although China has made great progress in promoting household energy practical technologies, but Taking Chinese great potential into consideration, lots of work remains to be done:

- 1) Enhance the propagandizing of relevant technology and knowledge, provide science popularization education for public, and improve the public awareness of energy saving and environmental protection.
- 2) Complete the policy system to play a leading role, and adjust the policies in industry and tax to provide sufficient and efficient policy encouragement for the R&D and promotion of practical energy technologies;
- 3) Enhance market supervision, strengthen the produce and devices quality monitoring system related with technology application, make relevant product quality standard and test methods, standardize market behavior, and prevent the fake and inferior goods and devices from damaging the enthusiasm of public application of energy saving or new energy technologies;
- 4) Establish complete service system. Government shall guide, promote service systems construction such as device repairing, technology consulting, information dissemination and technology training. Ensure habitants that energy saving goods can be well applied for a long time after installation;
- 5) Enhance the coordination between energy saving practical technology promotion with other policies and standards, such as: when promoting solar water heater, it should be consistent with building design, water supply, and achieve unified design, unified install, and construct green and energy saving residential buildings.

Thirdly, fully utilize international mechanism such as CDM or other market mechanisms, and enlarge the financing channel for household energy practical technologies promotion. The potential for such technologies in China is mainly focused on countryside and small towns, where residents have relatively lower income. The initial investment for such technologies are relatively high, therefore the financial problem is one of the major obstacles. Only when a stable financing mechanism is established, the constant promotion of such technologies can be ensured.

Fourthly, deepen the international cooperation in the household energy practical technology field. China is in the leading position in this area, and these technologies can be applied to other developing countries such as Africa, etc. Chinese government together with developed countries should actively promote these technologies in other developing countries. Focus on the household energy development policies of countries and regions in Africa, especially local social economy development, and make scientific and proper implementation plan based on local conditions; help developing countries utilize energy saving or new energy technology, to contribute to local sustainable

development and promote the international cooperation of coping with climate changes.

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