Applicability analysis of two kinds of clean heating products in rural area

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Abstract: This article compares the advantages and disadvantages of three decentralized clean energy heating products such as gas wall-hung boilers, air source heat pumps, and biomass heating. Through a rural case in Dezhou, it is recommended that the appropriate clean energy heating schemes should be determined based on local resource characteristics.

1. Introduction

The use of coal is an important cause of haze in northern China. Among the 160 million rural households, about 93 million are decentralized heating, including 66 million with coal-fired heating and 23 million with clean heating. Most of them are concentrated in northern areas, and the use of scattered coal is about 200 million tons. The pollution caused by the burning of poor quality loose coal in winter is huge, as shown in Table 1.

| Emissions       | Bulk coal | Power plant boiler |
|-----------------|-----------|--------------------|
| SO2 (kg/t of coal) | 4         | 0.8                |
| PM2.5 (Kg/ton coal) | 11        | 0.2                |

It can be seen from the Table that the emission coefficient of bulk coal is much higher than power plant boilers [1].

In March 2017, the “Beijing-Tianjin-Hebei and Surrounding Areas 2017 Air Pollution Prevention and Control Work Plan” was released. In this work, Beijing-Tianjin-Hebei air pollution transmission channel “2+26” city was listed as the first batch of winter clean heating planning implementation areas in the northern region, and the management of scattered coal in urban villages, urban-rural junctions and rural areas has been strengthened. In August 2017, the “Beijing-Tianjin-Hebei Autumn-Winter 2017-2018 Comprehensive Air Pollution Control Action Plan” was released, it puts forward detailed requirements for “coal to gas” and “coal to electricity” in many places. It requires 6 provinces to complete a total of 3.55 million households with a total of 3.55 million pilot demonstration during 3 years [2]. Currently, “2+26” cities have all issued local subsidy policies. The subsidy policies in some regions are shown in Table 2.
Table 2: Government subsidy policies for coal to gas & coal to electricity in some regions

| Area    | Subsidy of coal to gas (yuan/household) | Subsidy of coal to electricity (yuan/household) |
|---------|-----------------------------------------|-----------------------------------------------|
|         | Equipment Purchase | Use natural gas | Equipment purchase | Use electricity |
| Beijing | 72 million yuan    | 2440 yuan/year | 12,000 yuan(max)   | 2000 yuan/year  |
| Shijiazhuang | 3900 yuan(max) | 1680 yuan/year | 5000 yuan(max) | 900 yuan/year |
| Taiyuan | 5000 yuan(max) | 1500 yuan/year | 14400 yuan(max) | 2400 yuan/year |
| Zhengzhou | 3500 yuan(max) | 600 yuan/year | 2000 yuan(max) | 900 yuan/year |
| Jinan | 2700 yuan(max) | 1200 yuan/year | 2000 yuan(max) | 1200 yuan/year |
| Dezhou | 4000 yuan(max) | 1000 yuan/year | 4000 yuan(max) | 1000 yuan/year |

At present, the decentralized heating equipment suitable for the rural areas of our country mainly includes gas-fired boilers, air source heat pumps, biomass heating stoves, electric heaters and solar heating equipment. Among them, solar heating is greatly affected by the weather. Due to the large space of solar collectors, the large water storage tanks are required. Thus, it causes high system costs and less applications. Due to its low thermal efficiency and high costs, the electric heaters are not suitable for rural areas. Due to the high system price and the large amount of subsidy, the air source heat pump are mostly used in Beijing. This article takes a 100 m² rural building in Dezhou as subject, and the heating period is determined as 120 days. Moreover, two types of gas wall-hung boiler and biomass heating stove are selected for calculation of system characteristics, equipment cost, and heating operation cost. The equipment cost in this article includes the heating furnace, piping, heat dissipation equipment, water pump and other systems.

2. Comparison

2.1. Gas boiler

Wall mounted gas boiler is short for “wall-mounted gas heating water heaters”[3]. Gas-fired boilers originate from Europe, it has been used for hundreds of years.

1) Equipment advantages

- It has small size (380mm×240mm×700mm); it is easy to install, and it can meet the needs of both heating and hot water; its thermal efficiency can up to 90%; the system has a high degree of automation, and the fluctuation of indoor water temperature is small. The schematic diagram of the system is shown in Figure 1.

2) Equipment shortcomings

- Heating costs and effects are directly affected by natural gas price fluctuations and supply capacity; the operation leads to certain noise, about 30-40 decibels; it causes serious air pollution, generally 150mg/kWh.

3) Equipment cost

- Refer to the latest quotation, about 6500 yuan per set. In Dezhou, each household will get a subsidy of 4,000 yuan, and the actual investment is 2500 yuan.

4) Operating cost

- The calorific value of 1m³ natural gas is about 8500 Kcal, and the average daily gas consumption is about 16m³. Based on the thermal efficiency of 90%, the average daily heat requirement is 1.22×105Kcal. The natural gas price in Dezhou is 2.45 yuan/m³, and the heating period is 4704 yuan. The subsidy of Dezhou is 1000 yuan, and the annual operating cost in total is 3704 yuan.
2.2. Biomass boiler

The utilization of biomass resources in China includes biomass direct combustion, biomass shaped fuel (briquettes, pellets), biomass gas, and biological liquid fuel. Biomass briquetting fuel is extruded by using crop waste in the process of agricultural production through roller and die pressing equipment\(^4\). The mostly used agricultural production are sorghum straw, wheat straw, straw, sunflower straw, soybean straw and cotton. Moreover, board skins, wood chips and truncated residues are also included. After the processing of biomass fuel, the emissions of SO\(_2\), NO\(_2\), CO, PM\(_{2.5}\) and other pollutants are lower. The application of biomass particles is an important way to reduce carbon emissions. The pollutant emission factors of different products are shown in Table 3.

| Heating mode                      | SO\(_2\) | NO\(_2\) | CO    | PM\(_{2.5}\) |
|-----------------------------------|---------|---------|-------|--------------|
| Straw burning ondol               | 0.02    | 1.85    | 36.93 | 9.97         |
| Kang                              | 0.02    | 2.22    | 38.3  | 8.28         |
| Bulk coal heating                 | 1.78    | 2.05    | 61.05 | 3.73         |
| Shaped fuel heating stove         | 0.05    | 1.35    | 27.6  | 0.67         |

The small biomass heating stove used in decentralized heating includes a feed system, a combustion system, an air supply system, a water circulation system and an automatic control system. Biomass pellet heating stoves are divided into two types: hot air and water heating. The working principle of hot air biomass heating is shown in Figure 2. The heat of biomass particle combustion is brought to the heating environment by the blower; the working principle diagram of hot water biomass is shown in Figure 3.
Figure 2: Working principle diagram of hot air biomass heating

Figure 3: Working principle diagram of hot water biomass heating

1) Equipment advantages
It is simple to operate; due to the forced ventilation facilities, it has high safety and thermal efficiency; the equipment uses automatic ignition devices, only takes 3-5 minutes; stoves have automatic temperature control system. The speed of feeding and air supply can be adjusted according to the indoor temperature, and the degree of automation is high; the furnace thermal efficiency is about 80%.

2) Equipment shortcomings
The volume of the equipment is larger than that of the gas-fired boiler (500mm×500mm×1000mm). And there is a certain noise during operation, about 50 decibels; due to the limited volume of the silo, it is necessary to add biomass particles and clean the dust every day. it can run for 15-30 hours during one feeding; in the early stage of ignition, due to the lower temperature in the furnace, the CO concentration generated by the particle combustion is higher.

3) Equipment cost
At present, the small biomass pellet heating stoves on the domestic market are mainly domestic brands, and the water heating type is about 6,000 yuan. The government in Shandong province provides a subsidy of 2000 yuan for each stove of biomass decentralized heating stoves, and a subsidy of 600 yuan per ton for villager’s biomass fuel for heating, but no more than 2 tons per household per year.

4) Operating cost
The calorific value per kilogram of biomass wood pellets is about 4000 Kcal, according to the system thermal efficiency of 85%. With the heating energy of gas, the average daily biomass pellet consumption is 36 Kg. The consumption of biomass pellets for the entire heating season is 4320Kg. The market price of biomass pellets is about 1000 yuan/ton, so the cost is 3120 yuan after subsidies.

2.3. Comparative analysis
By comparing and analyzing the two decentralized heating products in this article, it can be seen that the two products have little difference in both system cost and operating cost, detailed in Table 4.
Table 4: Cost comparison table of three heating products

| Product          | Before subsidy | After subsidy |
|------------------|----------------|---------------|
|                  | System cost   | Operating costs | System cost | Operating costs |
|                  | (Yuan/set)    | (Yuan/year)   | (Yuan/set)  | (Yuan/year)    |
| Gas boiler       | 6500          | 4704          | 2500        | 3704           |
| Biomass boiler   | 6000          | 4320          | 4000        | 3120           |

3. Conclusions and recommendations

Accelerating the promotion of clean heating is an effective way to implement the air pollution prevention and improve the quality of the air environment. Good atmosphere and ecological environment are related to the fundamental interests of the people and the overall situation of economic and social development. At present, the situation of air pollution prevention and control in Shandong Province is still grim and complex. By accelerating the development of clean heating work with replacing scattered coal as the main content, it can effectively promote the optimization and adjustment of heating energy consumption structure, minimize the emission of main pollutants, and make positive contributions to reducing haze and building a beautiful Shandong Province. The promotion objectives of clean heating rate in various cities in Shandong Province are shown in Table 5.

Table 5: Promotion target of clean heating rate of prefecture-level cities in Shandong Province

| Region              | Nine key regions | Eight non-key areas |
|---------------------|------------------|---------------------|
|                     | 2020             | 2022                | 2020         | 2022         |
| County and urban-rural junction | 85%              | 100%                | 85%          | 100%         |
| rural area          | 60%              | 80%                 | 75%          | 90%          |

The nine key areas are Jinan, Qingdao, Yantai, Zibo, Jining, Dezhou, Liaocheng, Binzhou, Heze.

The eight non-key areas are Zaozhuang, Dongying, Weifang, Taian, Weihai, Rizhao, Linyi, Laiwu.

"Shandong Province Winter Clean Heating Plan (2018-2022)" stipulates that by 2022, the heating area of "solar and other clean energy" will strive to reach 5 million square meters. Through the analysis, it can be seen that each product has its own different characteristics, and users can choose the suitable product according to the geographical location, climatic conditions, building characteristics, installation conditions, government policies and other factors. With the expiration of the three-year demonstration, all local governments are also introducing new subsidy policies. Currently, they have formulated clearer preferential policies for “coal to power” and “coal to gas”, but there is no specific supporting policy. Thus it is urgent to introduce relevant policies. Finally, the advices proposed in this paper is to choose suitable products according to the specific local conditions, so as to avoid the situation that the equipment cannot be used again due to air cuts and low power.

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