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STUDY ON THE ADAPTABILITY OF CLEAN HEATING IN WINTER IN RURAL AREAS OF SHANDONG PROVINCE

Meng Wang[1], Zhong Ma[1],Yuxin Bai [1*]
School of Environment, Renmin University of China
1 Renmin University of China, Beijing 100872, China
1* Renmin University of China, Beijing 100872, China (Corresponding Author)

ABSTRACT

Promoting clean heating in winter in the northern region is related to the warmth of the masses in the northern region and whether fog and haze can be reduced. On the basis of summarizing the current situation of heating in rural areas of northern China, this paper expounds the practical problems and basic needs of clean heating.

Taking Shandong as the research object, this paper studies the applicability of different modes of clean heating technology in rural areas of North China.The author calculates the heat load demand during heating period, screens the suitable clean heating technology in Shandong area, and obtains the suitable technical path and application mode for rural clean heating in Shandong area.The technical feasibility, economic feasibility and environmental impact of different modes of clean heating, such as solar heating, gas heating and biomass pyrolysis multi-generation heating, are analyzed. The results show that under the existing economic and technological conditions, biomass pyrolysis polygeneration is suitable for clean heating in rural areas of Shandong Province, especially for demonstration and promotion of small centralized or decentralized heating in natural villages or new rural communities. This study provides a new way to solve the problem of clean heating in rural areas of northern China.

Keywords: Clean heating, clean energy, biomass, techno—economic, Pyrolysis polygeneration

1. INTRODUCTION

"Scattered charcoal substitution" is the primary task of heating in northern rural areas. In winter, air pollution in North China is getting worse, and coal for rural heating is one of the important reasons. According to the Clean Heating Planning for Winter in Northern China (2017-2021), the heating area of urban and rural buildings in northern China is about 20.6 billion M2 by the end of 2016, including 14.1 billion m^2 in cities and 14.1 billion m^2 in towns and 6.5 billion m^2 in rural areas.At present, coal is the main source of heating energy in North China. Coal-fired heating area accounts for 83% of the total area. Heating coal consumes about 400 million tons of standard coal. Bulk coal combustion (including coal for low-efficiency small boilers) is about 200 million tons, mainly distributed in rural areas. [1]This paper combs the planning, policy and technology of clean heating in northern China in recent years, analyses the cogeneration of heat and power, central heating, decentralized heating, renewable energy and multi-energy complementary heating, compares the initial investment and operation cost of rural heating mode in Shandong Province, and studies the formulation of mountain. Effective scheme of clean heating mode for urban and rural residents in East Province.To achieve clean heating in winter for urban and rural residents is of great practical significance for promoting green low-carbon development, accelerating the conversion of new and old kinetic energy, achieving the goal of air pollution prevention and control, and solving the current haze problem.

2. NECESSITY OF CLEAN HEATING IN RURAL AREAS

There are more than 32.5 million households in Shandong Province, including 13 million households in rural areas. The total heating area of urban and rural buildings is about 2.886 billion square meters, with a heating rate of 88.3%. Among them, urban heating area is 1.778 billion square meters, heating rate is 91.9%; rural heating area is 1.108 billion square meters, heating rate is 83.0%. Urban heating in the province has formed a development pattern of coal-fired cogeneration units and regional boilers, supplemented by decentralized heating of renewable energy such as natural gas, electric energy and geothermal energy. At present, there are about 43 million tons of heating coal in the province, of which about 10 million tons are used for heating bulk coal combustion, mainly concentrated in the vast rural areas. The average comprehensive energy consumption of heating in the province is about 20.3 kilograms of standard coal/square metre, of which the average comprehensive energy consumption of urban heating is about 18.0 kilograms of standard coal/square metre, and that of rural areas is about 24.0 kilograms of standard coal/square metre. In 2018, the average concentration of fine particulate matter ($PM_{2.5}$) was 49 ug/m^3; the average concentration of inhalable particulate matter (PM_{10}) was 97 ug/m^3; the average concentration of sulfur dioxide (SO_2) was 16 ug/m^3; and the average concentration of nitrogen dioxide (NO_2) was 36 ug/m^3. All the indexes were higher than the national level.[2]

At present, the urban central heating area of Shandong Province is about 1.4 billion square meters, and the popularization rate of central heating is 73%. In urban-rural areas and rural areas, decentralized heating is the main method, mainly using small coal stoves, soil heating, fire kang, air conditioning and so on, accounting for 79.0% of the total heating area; in other areas, centralized heating, natural gas, electric energy, biomass energy and other clean heating methods account for 21% of the total heating area. The area of clean heating in the province is about 1.77 billion square meters, with a clean heating rate of 54.3%. Among them, urban clean heating area is 1.53 billion square meters, with a clean heating rate of 79.3%; rural areas have a clean heating area of 240 million square meters, with a clean heating rate of 17.9%.[3]

3. CONTRAST OF HEATING TECHNOLOGY AND ECONOMY

3.1 Small Coal-fired Boiler

Most of the rural areas in Shandong Province now use small bulk coal stoves for heating in winter. The hot water is heated by combustion of loose coal and the indoor air is heated by the end of the heating sheet to achieve the heating effect. As a contrast, the heating economy of bulk coal stove is studied firstly. The heating area is less than 100 m2, and the end of bulk coal stove and heating sheet needs about 2,000 yuan investment. The formulas for calculating the cost of coal combustion to meet the heating load are as follows:

$$C = Q*p/q*\delta$$

In the formula: C is cost; Q is heat load demand; q is low calorific value of standard coal 29300 MJ/t; delta is coal furnace efficiency, set at 0.8; P is rural bulk coal price, at an average price of 650 yuan/t. Each small bulk coal boiler needs 2-3 tons of bulk coal in winter, and the operation cost of heating is 2662 yuan.

3.2 *Solar Heating*

When solar energy is used in heating system, the heating system is usually composed of solar collector, heat storage device and auxiliary heat source. In this study, the cost of solar heating is divided into initial investment cost and operation cost. The initial investment cost of solar heating system mainly includes the purchase cost of equipment and accessories such as solar collector, water tank, circulating pipeline, support, control system, heat exchanger and water pump, transportation cost of equipment and installation and commissioning cost of system. The price of collector and water tank accounted for more than 60% of the initial investment. The initial investment is related to the size of heating area. According to GB/T 23483-2009 "Building Enclosure Heat Transfer Coefficient and Heating Heating Detection Method" and GB/T 31156-2014 "Solar Energy Resources Measurement - Total Radiation", the initial investment calculation formula is as follows:

$$C_1=A\cdot S+T+R+C_{11}$$

Type A is the collector area; S is the collector price per square meter; T is the water tank price; R is the price of other parts of the system; C_{11} is the transportation and installation cost. Assuming Qi is an auxiliary heat source, solar energy collector is：

$$Qj=J_tDA\eta C_d（1-\eta 1）$$

In the formula: Q_j is solar energy heat collection; J_t is solar energy daily radiation cumulative measurement, MJ/(m^2d); D is heating days; A is flat plate collector area; C_d is collector heat efficiency, take 40%; η1 is heat loss rate of pipeline and heat storage device, take 20%.

The contribution rate of solar energy is the ratio of the total heat supply to the total heat supply of the solar collector system, which indicates the contribution degree of the solar collector system to the total heat supply.

$$f=Qi/Qi+Qj$$

The operating cost：$C_2=Q/\eta q\times p$

In the formula: C_2 is the operating cost, yuan; Q is the heating capacity of heating equipment; η is the efficiency of heating equipment; q is the calorific value of fuel; P is the unit price of fuel.By calculation, the results in Table 1 are obtained.

Table 1 Costs and parameters related to solar heating

	Name	Solar heating
1	Average heat consumption/W	9500
2	Solar Energy Guarantee Rate	0.15
3	Heating collector area/m2	22
4	Water tank volume/L	2000
5	Total heating load/M J	96000
6	Initial cost/yuan	45000
7	Operational costs/yuan	9000

3.3 Air source heating

Air source heat pump uses outdoor air as low temperature heat source, mainly through extracting heat from outdoor air, using the phase change process of refrigerant, transferring heat to indoor, to achieve the purpose of heating. The principle of air source heat pump technology is that heat pump unit mainly transfers heat from low temperature heat source to high temperature heat source by consuming a part of electric energy.[4]

Through the actual research and development of coal-to-electricity conversion projects in Yinan County and Yishui County of Shandong Province, it is found that the COP is between 2.5 and 3. In the study of Jiang Yi (2017)[5], it is also pointed out that the COP of air source heat pump in southern Beijing can reach more than 2. Considering comprehensively and conservatively, the COP of air source heat pump is 2.5. The calculated heat load demand is matched hourly. The economy of the air source heat pump heating system is shown in Table 2. The running cost of the system is the heat pump power consumption (based on the local clean heating peak and valley price).

Table 2 Relevant parameters of air source heat pump units

state:35℃/24℃	Nominal refrigeration capacity/kW	12.5
water temperature:12℃/7℃	Rated input power/kW	4.5
state:7℃/6℃	Nominal calorific capacity/kW	14.6
water temperature:40℃/45℃	Rated input power/kW	4.49
Max effluent temperature/℃		60
circulation water/(m3/h)		2.5
Initial cost/yuan		37750
Operational costs/yuan		4360

3.4 *Gas Wall-mounted Furnace*

Gas wall-hanging furnace heating is only applicable to the areas where the gas pipeline network has been built. Otherwise, the cost of using canned gas is huge. The economic calculation of gas heating is based on the current gas price in local cities and towns, without considering the factors that the gas price in rural areas is higher than that in urban areas due to the difficulty of pipeline network construction. In this study, domestic gas wall-mounted furnaces are used, and the thermal efficiency of gas fuel chemical energy converted into heat energy is about 80% - 90% (the maximum efficiency of domestic boilers is 90%). The heat recovery efficiency here is 85%. The heat loss and other losses in heat transfer process are basically the same, assuming that all of them are a, this paper takes a = 1. The overall thermal efficiency of gas wall-mounted furnaces is as follows:$\beta=100\%\times85\%\times a=85\%a=85\%$；

Cash Balance Formula of Gas Wall-mounted Furnace：

$$C_fE_f+Z_n=C_wE_w+C_hE_h$$

Average output cost is C：

$$C_fE_f+Z_n=C（E_w+E_h）,$$

$$C=C_fE_f+Z_n/E_w+E_h ;$$

C_f is the cost of natural gas; E_f is the annual consumption of natural gas; Z_n is the annual non-energy cost of gas wall-mounted furnace; C_w is the cost of supplying domestic hot water; E_w is the output of supplying domestic hot water; C_h is the cost of heating; E_h is the output of heating; C is the average output cost of gas wall-mounted furnace.

If the normal heating time is 120 days, the average daily operation time is 16 hours and the average gas consumption per hour is 2 m^3, the gas consumption for winter heating is 3840 m^3, and the price of natural gas in Jinan is 3.3 yuan/m^3, which is at the average level in the whole province. For gas-fired boilers, the heating price should be calculated at 3.3 yuan/m^3. table 3,The initial cost of gas wall-mounted furnace is 19 300 yuan, and the operation cost of heating in winter is 12 672 yuan.

Table 3 Gas Wall-mounted Furnace Cost and Equipment Parameters

No	Name	Gas Wall-mounted Furnace
1	Rated heat load	25KW
2	Actual heat load	23.3KW
3	Rated heating output	22.5KW
4	Actual heating output	21KW
5	Market price	15000yuan
6	Installation fee	4000yuan
7	Maintenance fee	300yuan
8	Life span	8years
9	Air consumption during heating period	3840m3
10	Water consumption in winter	40L/person

3.5 *Pyrolysis Polygeneration of Biomass*

Biomass carbonization technology, also known as biomass retorting technology, belongs to the category of biomass thermochemical conversion technology. It refers to the process in which biomass raw materials decompose into biochar, bio-oil and non-condensable gas products by heating and warming in the adiabatic or hypoxic environment.[6] The clean cycle heating mode based on co-production of carbon, gas and oil is suitable for rural clean heating with natural villages as the main body. The liquid products separated after pyrolysis include wood tar and wood vinegar. All wood tar is recycled and burned to heat the carbonization and drying systems, and vinegar is used as pesticide in agriculture. Biochar includes straw charcoal and charcoal, in which straw charcoal is mixed, conditioned and processed to produce carbon-based fertilizer for in-situ use, and charcoal is crushed and moulded to produce machine-made charcoal, which is heated by special stoves for farmers in winter. Because the demand for gas varies greatly in summer and winter, the equipment can operate under different load modes.

Based on the investigation of Yinan and Yishui counties in Shandong Province, the following data are obtained. The consumption of pyrolysis gas per household in heating season is 15-18 m^3/d (including cooking gas 1 m3/d, pyrolysis gas calorific value > 15 MJ/m3), which requires a set of continuous pyrolysis equipment with a raw material processing capacity of about 1 t/h and a daily gas production of about 3500 m^3. The heating period is calculated by 120 days, and the amount of biomass raw materials needed to be treated is 3000T. Because of the different uses of straw charcoal and charcoal, the ratio of straw raw material to lignin raw material is calculated as 1:1.

Dry straw and pruning (moisture content not exceeding 15%) to the factory price of 300 yuan/t, the power consumption in operation is mainly used for crushing raw materials, each crushing ton of raw materials needs 30 kW.h. The carbonization rate of straw is 40%. The price of straw charcoal as the raw material of carbon-based fertilizer is estimated at 1200 yuan/t. The price of charcoal as the raw material of machine-made charcoal is 3000 yuan/t. The price of gas is 1.2 yuan/m3. The depreciation of equipment is calculated at 8 years. Table 4, the gross profit of this model is 1.07 million yuan and the investment can be recovered in 3 years.

4. RESULTS AND DISCUSSION

From the above analysis, we can see that:

(1) Gas heating system is only applicable to the areas where gas pipeline network has been built, and the gas price in rural areas is higher than that in urban areas, and the annual operating cost is higher than that calculated above.

Table 4 Summary of Input-Output Costs of Biomass Pyrolysis Polygeneration

Cost Composition	project	Cost/Ten thousand yuan	Remarks
Initial investment	Equipment, land	300	Straw, prune
Operational costs	raw material	90	Straw, prune
	Employee Wages	3.6	3000 yuan/month, three people
	Electricity fees	8.1	0.9yiuan(kW·h)
	Other expenses	10	Water and maintenance costs
income	Straw charcoal	162	1200yuan/t
	Biogas	50.4	1.2yuan/m3
Annual profit		100.7	No initial investment

(2) Compared with the gas wall-mounted furnace heating system, the initial investment increase cost of air source heat pump system can be recovered in a relatively short time (about 6 years), while the service life of air source heat pump system is about 16 years, and the air source heat pump heating system is better.

(3) The investment of biomass pyrolysis polygeneration is higher in the early stage, but the continuous biomass carbonization technology has the advantages of high production efficiency, stable product performance and convenient process control. Based on the continuous pyrolysis carbon-oil co-production model, biomass pyrolysis can derive a variety of co-production models, and the initial investment cost can be recovered in a relatively short time. (3) About one year. It is suitable for small-scale centralized or decentralized heating in natural villages or new rural communities. The technical scheme can provide new ideas and ways to solve the problem of clean heating in rural areas of northern China.

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Author:

Meng Wang：Ph.D. in Population, Resources and Environmental Economics.

Zhong Ma： professor，Doctoral Supervisor.

Yuxin Bai :Ph.D. in Population, Resources and Environmental Economics.

Corresponding Author

E-mail byxinn@163.com.