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The Prospects of Geothermal Industry in Rural Areas

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ABSTRACT

Clean heating in rural areas is the focus and difficulty of clean heating in Northern China. Since 2017, rural areas have adopted electricity and gas as the main means of promotion, having problems such as high operating costs, tight gas sources, and unsustainable. In order to further promote clean heating in rural areas, this paper divides rural residential houses into distributed and concentrated houses. Through carry out technology and economic comparisons of geothermal, gas, biomass and electric, the suitable method for clean heating in rural areas is studied. The research results show that: The household ground source heat pumps are suitable for distributed houses, with high heating efficiency, low energy consumption, and low heating operation costs. Based on calculating of savings of operating costs, the difference in initial investment for different heating methods is analyzed, and the upper limit of the investment for household ground source heat pumps is 374.46 yuan/m^2. Medium-to-deep geothermal heating is suitable for concentrated houses with no carbon emissions and low operating costs. Meanwhile, rural areas in Northern China are rich in geothermal resources, which can meet clean heating needs of rural areas. It is recommended to construct household ground source heat pumps demonstrations in energy-saving distributed rural areas with high government subsidies and high disposable incomes while construct medium-to-deep geothermal heating demonstration in concentrated rural houses with rich geothermal resources and high heating prices. The government should consider increase subsidies for initial investment in geothermal heating, adjust the subsidy structure for household ground source heat pumps, and introduce subsidy policy for medium-to-deep geothermal heating system. Conclusion: Geothermal heating is environmental friendly, and is a method of “subsidy of initial investment but not operating”, which is suitable to promote in northern rural areas.

1. INTRODUCTION

Since 2014, haze has occurred frequently in many provinces in China, which has seriously affected people's health, production and life (Wang, Gu and Chen, 2016), (Chen, et al, 2019), and the burning of coal is an important factor causing haze (Wei, et al, 2014), (Andersson, et al, 2015). At the 14th meeting of the Central Financial and Economic Leading Group held on December 21st, 2016, General Secretary Xi Jinping emphasized the need to promote clean heating in winter in northern regions (Central Finance and Economic Leading Group, 2015). Driven by the state and governments at all levels, the rate of clean heating in northern China has been increasing since 2017. By the end of 2020, the rate of clean heating has risen to over 60% (Ministry of Ecology and Environment of the People’s Republic of China, 2021), but only 28% in rural areas (Xinhua News Agency, 2020), much lower than the overall clean heating rate in the northern region. At present, the clean heating in rural areas is mainly based on "coal to gas" and "coal to electricity", and there are only a few pilot projects for "coal to heat" and "coal to biomass"(Research Center for Building Energy Efficiency of Tsinghua University, 2020). In the process of promoting "coal to electricity" and "coal to gas", some problems have been exposed. First of all, the government subsidizes three aspects including the pipeline network construction, the equipment purchase, and the operation, which creates great financial pressure. According to statistics, during the “13th Five-Year Plan” period, the central government alone invested 49.3 billion yuan to support clean heating in 43 pilot cities (Huang, 2021). Secondly, the residential buildings in rural areas are distributed and the infrastructure construction is poor. It is necessary to lay a natural gas transmission and distribution pipeline network or to transform each household's power distribution capacity and village-level transformers. Gas and power grid companies have low return on investment and thus have low enthusiasm. Thirdly, the energy consumption of rural houses is high and the per capita disposable income of rural residents is low. The operation cost of clean heating has caused an economic burden to farmers. In view of the above problems in the promotion of "coal to electricity" and "coal to gas" in rural areas, according to the characteristics of rural houses, this paper compares and analyzes two different types of clean heating in distributed rural houses and concentrated living in new rural areas, and tries to explore suitable clean heating method in rural areas to form a long-term market mechanism and promote the development of clean heating in rural areas.

2. TECHNICAL AND ECONOMIC COMPARISON OF CLEAN HEATING METHODS FOR DISTRIBUTED RURAL HOUSES

Distributed rural houses are a traditional form of village aggregation in Northern China. Most of them are distributed along mountains, hills, and rivers. The centralized heating method requires the laying of long-distance pipeline networks, and the investment cost is high, so it is not suitable for use. Household ground source heat pumps, air source heat pumps, carbon crystal plate heating, gas wall-hung boilers, and biomass fuel furnaces are five commonly used distributed heating methods for distributed rural houses. In order to carry out the comparative analysis, take the square of rural house as 100 m^2, the heat index as 55 W/m^2, the equipment usage time as 12 h, and the heating period as 120 days for calculation (Table 1).Sections and subsections should be numbered.

2.1 Technical Comparison

Based on the introduction of household ground source heat pump, air source heat pump, gas wall-hung boiler, biomass fuel furnace and carbon crystal plate heating, the energy types, heating efficiency and heating energy consumption per unit area of five clean heating methods are compared.

Household ground source heat pump is a new type of heat pump system developed on the basis of ordinary ground source heat pump and suitable for rural areas. One or two wells are drilled in the open space of rural house with a depth of about 100 m as heat source of the heat pump, which can realize heating in winter and cooling in summer. Except for the mountainous areas, most of the rural areas in the Northern have good soil source conditions and are suitable for household ground source heat pumps. Its advantages are that the system operates stably, is less affected by the outdoor ambient temperature, and has good adaptability to the existing power grid in rural areas, and does not require additional power grid reconstruction, and can generate 3-4 kWh of thermal energy for every 1 kWh of power consumed (Bai, et al, 2019), (Luo, et al, 2021), (Liu and Chen, 2019). However, its installation workload is large, and needs enough space for drilling wells and burying pipes.

Air source heat pump utilize low-grade heat energy in the air to achieve heating and cooling. Its advantages are that the system is highly efficient and energy-saving, the COP is above 2, and its efficiency increases with the increase of the outdoor temperature (Xing, et al, 2021); however, the air source heat pump is greatly affected by the ambient air temperature, and the equipment efficiency decreases with the decrease of the temperature, and there is a problem of frost. In the severe cold period, the heating capacity decreases, thus it is not suitable for use in severe cold areas.

Gas wall-hung boiler burns gas supplied from the external grid for heating. It is suitable for whole-village promotion in suburban areas of cities where there is sufficient gas source and users are relatively concentrated (Shan, et al, 2020). The advantages are simple operation and convenient use; however, because the working principle is that a high-grade heat source convert into a low-grade heat source, there is a problem of high energy and low use. At the peak of natural gas consumption, the "gas shortage" is aggravated, and the dependence of natural gas on foreign countries is intensified; at the same time, due to the incomplete infrastructure in rural areas, most of them need to lay outdoor natural gas main line pipe networks and indoor branch pipes.

Biomass fuel furnace utilize agricultural and forestry wastes, and turns wastes into treasures, and can solves the problem of open burning of straws. It has good comprehensive environmental benefits and is suitable for large-scale applications in rural areas rich in agricultural and forestry biomass resources (Shan, et at, 2021). The combustion efficiency of biomass fuel can reach about 70% when used with a special heating furnace; however, the distribution of biomass resources is uneven. In areas where biomass resources are not abundant, high transportation costs lead to high prices of biomass fuel.

Carbon crystal plate heating is an electric direct heating method. It is suitable for promotion in areas with high power grid capacity, heating area less than 40 m^2, and no heating end (Guo, Huang and Zhang, 2019). Its advantages are simple operation and convenient movement; however, there are also problems of high energy and low use, low heating efficiency, and high requirements for grid capacity.

From the perspective of energy use, household ground source heat pumps and air source heat pumps use electricity as driving energy, gas wall-hung boilers use natural gas, biomass fuel furnace uses biomass, and carbon crystal panels use electricity as energy. By comparing the heat extraction efficiency and the energy consumption per unit area (Table 1), it is found that the household ground source heat pump has higher efficiency, the COP can reach 3.5, and the energy consumption is lower.

Table 1: Technical comparison of 5 common clean heating methods for distributed rural houses

Number.	Type	Energy type	COP/Heating efficiency	Heating energy consumption per unit area/(kg standard coal/m^2)(Zhang, 2015)	applicability
1	Household ground source heat pump	electric	3.5	5.54	Most areas except mountainous areas
2	Air source heat pump	electric	2.5	7.76	Areas other than severe cold areas
3	Gas wall-hung boiler	gas	0.9	21.52	Sufficient gas source and complete pipe network facilities
4	Biomass fuel furnace	biomass	0.7	27.64	Rich in agricultural and forestry biomass resources
5	Carbon crystal plate heating	electric	0.9	21.56	High power grid capacity, small heating area, and no heating terminal

2.2 Economic Comparison

2.1.1 Operating Cost

The heat required for the heating period of the rural house is 5544 kWh, and the biomass fuel cost is 1000 yuan/t (Cheng, Liu and Hou, 2021), thus the operating costs of the five clean heating methods are calculated (Table 2). The results show that the operating cost of the household ground source heat pump is the lowest at 8.71 yuan/m^2, and the operating cost of the air source heat pump, the gas wall-hung boiler, the biomass briquetting fuel, and the carbon crystal plate is 1.4, 1.97, 2.23, and 3.88 times of ground source heat pump, respectively. Under the control of a reasonable heating cost of 10 yuan/m^2 in rural areas (Yang, et al, 2021), only the operating cost of the household ground source heat pump can be accepted by farmers. According to the subsidy policy for the non-coal zone in Langfang, Baoding, Hebei Province (The People's Government of Hebei Province, 2016), under the government subsidy, three clean heating methods can be accepted by farmers, there are household ground source heat pump, air source heat pump and gas wall-hung boiler.

Table 2: Operating costs of 5 common clean heating methods for distributed rural houses

Number	Type	Energy Price	Fuel usage amount	Fuel cost/(yuan/m^2)	Fuel cost after subsidy/(yuan/m^2)

1	Household ground source heat pump	0.55 yuan/(kW·h)	1584kW·h	8.71	5.54
2	Air source heat pump	0.55 yuan/(kW·h)	2217.6kW·h	12.2	7.76
3	Gas wall-hung boiler	2.68 yuan/m^3	640.41m^3	17.16	10.76
4	Biomass fuel furnace	1000yuan/t	1.94t	19.4	19.40
5	Carbon crystal plate heating	0.55yuan/(kW·h)	6160kW·h	33.88	21.56

2.1.2 Initial Investment

Based on the savings of operating costs, the difference in initial investment of different clean heating methods is calculated, so as to estimate the upper limit of initial investment. Firstly, comparing the air source heat pump and ground source heat pump projects, for the above rural house, when the equipment life is 20 years, and not consider the subsidy, the ground source heat pump can save 3.49 yuan/m^2 of operating costs per year. Taking the inflation rate as 3%, and calculate by formula (1), the upper limit of the investment difference between the household ground source heat pump and the air source heat pump is 51.92 yuan/m^2 (Table 3), that is, when the investment amount of household ground source heat pump is less than 51.92 yuan/m^2 of air source heat pump, the economy of the household ground source heat pump project is better.

$$-X+\frac{3.49}{(1+3\%)}+\frac{3.49}{(1+3\%)^2}+...+\frac{3.49}{(1+3\%)^{20}}=0 \quad (1)$$

Table 3: Cash flow of initial investment difference

	Evaluation period					
	0	1	2	···	19	20
Air source heat pump		12.2	12.2	12.2	12.2	12.2
Ground source heat pump	X	8.71	8.71	8.71	8.71	8.71
Difference	-X	3.49	3.49	3.49	3.49	3.49

Set other equipment life period to be 20 years, and the difference in initial investment of air source heat pump and gas wall-hung boiler, gas wall-hung boiler and biomass fuel furnace, biomass fuel furnace and carbon crystal plate heating is respectively as 74.09 yuan/m^2, 33.92 yuan/m^2 and 214.53 yuan/m^2. Suppose the purchase cost of carbon crystal plate heating is 0 yuan/m^2, and the upper limit of the initial investment of household ground source heat pump is calculated to be 374.46 yuan/m^2 (Table 4). Combined with the literature and the survey of clean heating projects in 10 rural areas such as Xiongxian, Boye in Hebei Province and Daxing, and Mentougou in Beijing (Table 4), the initial investment of household ground source heat pump equipment is relatively high, but it is lower than the investment upper limit, which is still a clean heating method that can be accepted by the government, enterprises and rural residents.

Table 4: Upper limit of initial investment and literature research data yuan/m^2

Heating Method	Upper limit of Initial investment	Research Data	Chinese Academy of Architecture(Xu, et al, 2018)	Jinan Municipal Engineering Design and Research Institute (Cai, et al, 2019)	GCL Group Design and Research Institute (Wang, et al, 2018)	China Petroleum Planning Institute (Zhou, et al, 2020)
Ground source heat pump	374.46	210	280	350		
Air heat pump	322.54	190	260	250	377.5	220
Gas wall-hung boiler	248.45	50	120	80	190	39
Biomass fuel furnace	214.53	40	75			
Carbon crystal plate heating	0	30		30		

Based on the above analysis, the household ground source heat pump is a clean heating method of "subsidy of initial investment but not operating", which is suitable for promoting in distributed rural houses. In terms of technology, the household ground source heat pump has high heating efficiency and low heating energy consumption, which can realize energy saving and emission reduction; at the same time, its system is stable and has wide applicability, which is suitable for most rural areas in China except mountainous areas. In terms of economic, household ground source heat pumps have low operating costs, heating does not bring economic burden to rural residents, and does not require government subsidies for operating costs. Though initial investment is higher than other clean heating methods, still lower than the investment upper limit and when considering the operating costs, the economic of ground source heat pump is better.

3. TECHNICAL AND ECONOMIC COMPARISON OF CLEAN HEATING METHODS FOR CONCENTRATED RURAL HOUSES

Currently, the concentrated new rural areas in northern China are generally low-rise buildings with about 6 floors. The building type and residential density are similar to urban buildings. Central heating methods are suitable for new rural areas, including medium-to-deep geothermal heating, concentrated ground source heat pump, concentrated air source heat pump, gas boiler, electric heating and so on. Taking a place in Hebei as an example, the heating area is 200,000 m^2 for concentrated living in a new rural area, and the heat index is 40 W/m^2.

3.1 Technical Comparison

Based on the introduction of medium-to-deep geothermal heating, centralized ground source heat pump, centralized air source heat pump, gas boiler, and electric boiler, the advantages and disadvantages of five clean heating methods are compared.

Medium-to-deep geothermal heating technical routes are drilling geothermal wells, using underground hot water as a medium to extract underground thermal energy to the ground, and using plate heat exchangers and heat pump units for cascade utilization of heat, and recharging geothermal tail water into the same layer without pressure. For example, the geothermal heating project carried out by Sinopec in Xiongxian County, Hebei Province, has created a replicable and popularized "Xiong County Model" （Economic Information Daily, 2018）. In 2016, Sinopec expanded the geothermal heating in the urban area of Xiongxian County to rural areas, and carried out a pilot project in Shaxinzhuang, which has successfully operated for 5 heating seasons, with good promotion and demonstration effects (Gong, et al, 2017). Its advantages are clean and environmentally friendly, and zero carbon emissions; however, it has high requirements for geothermal resources, and needs to be used in areas with good geothermal resources and the project requires a large amount of engineering, including drilling geothermal wells and building heat exchange stations.

Concentrated ground source heat pump is different from household ground source heat pump system, the concentrated ground source heat pump needs to build an energy station and an outdoor transmission pipe network. Its advantage is that under the influence of scale effect, the energy efficiency of the concentrated ground source heat pump system unit is high, which can reach 5 (Liu, 2018); but in the case of single heating, it will cause the problem of cold accumulation of soil and the system efficiency will be affected.

The centralized air source heat pump uses a high-power model, and the single capacity can reach 800 P, while the maximum capacity of the traditional air source heat pump is only 25 P. Its advantage is that the overall efficiency of the unit is higher than that of ordinary air source heat pump units (Zhao, Wang and Han, 2018), but it is still affected by the ambient temperature.

Gas boiler uses natural gas combustion to heat water to meet people's heating needs. The advantage is that the heating guarantee capacity is strong, but has the problem of high energy and low use and need to build the natural gas pipeline network.

Electric heating use electricity as energy, and use resistance for heating. The advantage is that it is easy to install, but has the problem of high energy and low use and requires high power grid capacity.

From the perspective of energy use, medium-to-deep geothermal heating utilizes medium-to-deep geothermal resources, which is clean, environmentally friendly and pollution-free. The centralized ground source heat pump and the centralized air source heat pump use electricity as the driving energy, and the energy utilization efficiency is high. Gas-fired boilers use natural gas as energy, and electric heating use electricity as energy, both have problems of high energy and low use.

3.2 Economic Comparison

Use the heating rate as 65%, and the heating fee as 16 yuan/m^2 to calculate the cash inflow and outflow of the five concentrated heating methods (Table 5). The results show that the medium-to-deep geothermal heating has the lowest operating cost and the lowest total cost, enterprises can recover their investment through operation, and the project is economical. The operating costs of other four methods are high, and the heating fee income cannot cover the total cost.

Table 5: Economic comparison of 5 common clean heating methods for concentrated rural houses

Type	Unit investment/(yuan/m^2)	Fuel usage amount	Unit operating cost/(yuan/m^2)	Unit total cost/(yuan/m^2)	Internal Rate of Return（IRR）
Medium-to-deep geothermal	140.98	1,600,000 kW·h	5.69	11.48	8.12%
Concentrated ground source heat pump	176.47	4,996,000 kW·h	13.87	22.32	<<0
Concentrated air source heat pump	105.89	6,560,000 kW·h	16.31	21.4	<<0
Gas boiler	30	1,560,000 m^3	17.4	19.21	<<0
Electric heating	90	16,000,000 kW·h	30.68	36.11	<<0

Based on the above analysis, medium-to-deep geothermal heating is a clean heating method suitable for promotion in new rural areas of concentrated living. At the technical level, medium-to-deep geothermal heating can truly achieve zero carbon emissions and achieve green and sustainable development. At the economic level, first of all, the government only needs to subsidize the initial investment at one time, and does not need to continuously subsidize the operating cost, so the financial pressure is small. Secondly, the operating cost is low, and the geothermal heating enterprise can operate the project sustainably. Thirdly, the heating cost for rural residents is basically the same as that of burning coal, and the geothermal heating effect is better and the comfortability is improved.

4. FACTORS THAT AFFECTING THE PROMOTION OF GEOTHERMAL INDUSTRY IN RURAL AREAS

According to the technical and economic analysis, household ground source heat pump and medium-to-deep geothermal heating are suitable for promoting in distributed rural houses and concentrated rural houses in new rural areas, respectively, and it is clear that the geothermal industry can play an active role in clean heating in rural areas. In order to promote the development of geothermal industry, the factors affecting the promotion of geothermal industry in rural areas were analyzed.

4.1 Thermal performance of rural houses

The heat index of rural house is determined by factors such as the shape coefficient and the building envelope heat transfer coefficient [8]. Most of the concentrated rural areas in new rural areas are newly built buildings with good thermal performance. For distributed rural houses, with the increase of the heat index of the rural houses, the thermal insulation of the rural houses deteriorates, and the operating cost of clean heating increases (Figure 1). Therefore, in order to ensure the effect of clean heating, priority should be given to newly-built rural houses with a thermal index below 50 W/m^2 or rural houses with energy-saving renovations. For distributed rural houses with a thermal index higher than 100 W/m^2, clean heating operating costs are high and the effect is limited, so they are not appropriate to promote clean heating.

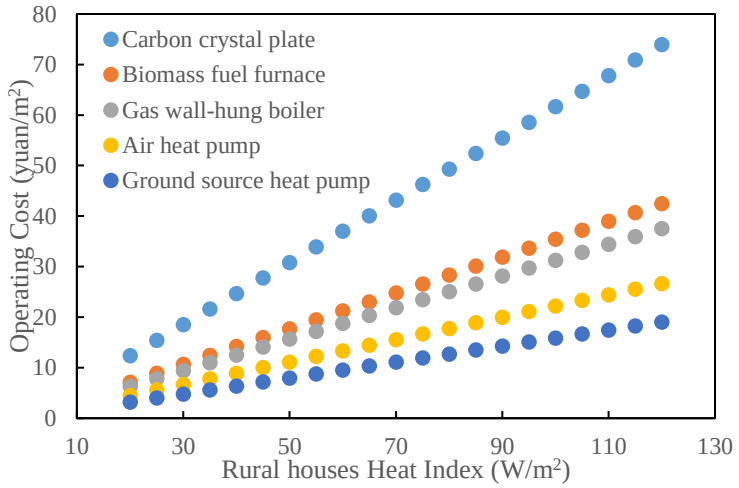

Figure 1: Operating costs changes with the heat index of distributed rural houses

4.2 Resource Conditions

China is rich in medium-to-deep geothermal resources. Only the Xiongan New Area and the surrounding ancient buried hills have a hot water resource of 52.6 billion m^3, and the available geothermal water resource is 33.61 billion m^3 (Luo et al, 2021). Most of the "2+26" cities and Fenwei Plain 11 cities are located in the Bohai Bay Basin, the Fenwei Graben, the Southwest Shandong Uplift and the South North China Basin (including a series of small basins such as the Zhoukou Basin), where sedimentary basin-type geothermal resources are widely developed, which has a high degree of matching with the demand of clean heat sources. However, the distribution of geothermal resources is not uniform, resulting in great differences in the effect and economy of geothermal heating in different regions. In order to systematically analyze the differences in geothermal resource endowments in the rural areas of Northern China, it is recommended to use indicators such as thermal storage type (directly affecting recharge ability), buried depth, water temperature, and water volume (Table 6) to divide the “2+26” cities and Fenwei Plains 11 cities into favorable areas, relatively favorable areas and general areas. Due to the mandatory temperature index required by the government, geothermal heating enterprises need to match heat pumps in areas with poor resources to ensure heating effect, which directly affects the cost of geothermal heating enterprises. In order to ensure the healthy and sustainable development of geothermal industry, priority should be given to the development of geothermal resources in favorable and relatively favorable areas.

Table 6: Classification standard for medium-to-deep geothermal resources

	Thermal Reservoir Type	Buried Depth	Temperature	Volume	Reservoir Properties	Recharge Cability	Representative City
Favorable areas	Carbonate	Moderate	High	Big	Good	Full recharge	Xiongxian
Relatively Favorable areas	Carbonate /Sandstones	Relatively Deep	Relatively high	Relatively Big	General	High recharge rate	Qingfeng
General areas	Carbonate /Sandstones	Deep	General	General	Poor	Need further research	Weixian

4.3 Government Subsidy

Currently, household ground source heat pump projects enjoy the subsidy of "coal-to-electricity", but the subsidy intensity of each province is quite different. Shanxi Province has the largest subsidy, among which Taiyuan, Luliang, and Jinzhong subsidy are higher than 100 yuan/m^2; Shaanxi Province subsidy intensity is lower, among which Weinan, Tongchuan and Baoji subsidies are less than

50 yuan/m^2. The subsidy amount of Taiyuan City, which has the highest government subsidies, is nearly 20 times that of Baoji City, the lowest. In terms of medium-to-deep geothermal heating, China has not yet issued a subsidy policy, and the subsidy methods implemented vary widely. Tianjin, Langfang, Shijiazhuang and other places refer to the subsidies of "coal-to-electricity" and "coal-to-gas", and Tongchuan, Weinan and other places give each household a fixed subsidy amount, Puyang and Hekou give a fixed subsidy amount per unit area, but there are places still have no subsidy methods (Table 7). The intensity of government subsidies affects the enthusiasm of geothermal enterprises. It is recommended to give priority to the promotion of geothermal heating projects in places with high government subsidies.

Table 7: Subsidy measures for medium-to-deep geothermal heating

Provinces	Cities	Subsidy measures
Beijing	Beijing	Heat source and primary pipe network, 50% subsidy
Tianjin	Tianjin	Refer to subsidy of "coal-to-electricity" and "coal-to-gas"
Henan	Puyang	40 yuan/m^2。
Shaanxi	Tongchuan	One-time subsidy of 4,000 yuan per household
	Weinan	One-time subsidy of 3,000 yuan per household
Shandong	Hekou	15 yuan/m^2, three years
Hebei	Langfang	Refer to subsidy of "coal-to-electricity" , one-time investment subsidy of 7,400 yuan per household, three years operating subsidy 1,200 yuan per household
	Shijiazhuang	Refer to subsidy of "coal-to-electricity" , one-time investment subsidy of 7,400 yuan per household, three years operating subsidy 1,200 yuan per household
	Xingtai	Refer to subsidy of "coal-to-electricity" , one-time investment subsidy of 7,400 yuan per household, three years operating subsidy 1,200 yuan per household

4.4 Disposable income of rural residents

Although the government currently bears a large part of the cost of clean heating, rural residents still need to bear part of the costs of clean heating in the actual operation process. The economic affordability of rural residents is relatively weak. Although geothermal heating has the lowest costs among various clean heating methods, it cannot be fully covered in rural areas in Northern China in a short period of time. It is recommended to give priority to promoting geothermal cleaning in areas with high disposable income of rural residents. According to the 2020 National Economic and Social Development Statistical Bulletin of each pilot city, the disposable income of rural residents in Beijing and Tianjin is higher than 25,000 yuan, which has great potential to promote geothermal heating; Zhengzhou, Jiaozuo, Hebi in Henan, Zibo, Jinan, Binzhou, Jining, Hebei Tangshan, Langfang, and Taiyuan, Shanxi, where the disposable income of rural residents is higher than 15,000 yuan, should also be the key areas to promote geothermal heating; Shaanxi's Xianyang, Tongchuan, Shanxi Yuncheng, Luliang and other areas have rural residents whose disposable income is less than 13,000 yuan , the ability of rural residents to bear the cost of clean heating is low, and geothermal heating should be promoted after all conditions are suitable.

4.5 Heating Cost

For central heating, the heating price is directly related to the income of heating enterprises and affects the economics of the project. Through research, the heating price in Shandong Province is relatively high, higher than 20 yuan/m^2, and the price in Jinan is 26.7 yuan/m^2; the heating price in Shanxi Province is generally low, and the heating cost in Taiyuan is only 18 yuan/m^2, and Changzhi and Jincheng are 13.2 yuan/m^2. In order to ensure the healthy and sustainable operation of the project and protect the enthusiasm of heating enterprises, priority should be given to promoting medium-to-deep geothermal heating projects in areas with high heating price.

5. REALIZATION PATH OF ACCELERATING THE PROMOTION OF GEOTHERMAL HEATING IN RURAL AREAS

5.1 Strengthening energy-saving renovation of rural houses in Northern areas

Most of the rural houses in China were built by rural residents, and more than 80% of the buildings have no energy-saving measures. According to the calculation, adopting the energy-saving renovation of rural houses by adding 60mm extruded polystyrene board outside the outer wall, using single-frame double-glass plastic-steel external windows instead of single-layer glass, and adding 27mm extruded polystyrene board to the roof can effectively reduce the heat transfer coefficient of external wall, external window, roof, and the heat index of the rural house is reduced from 98.7 W/m^2 to 55 W/m^2, and the renovation cost is 111 yuan/m^2, and the annual operating cost is saved by 45%. Judging from the current subsidy policy in Hebei Province, the subsidy for each household only for equipment purchase and three-year operation cost is higher than 100 yuan/m^2 (Table 8). Commence the work of energy-saving renovation of distributed rural houses and strengthen the insulation of building walls, doors, windows, and roofs can reduce the operating costs and achieve a multiplier effect.

Table 8: Hebei Province three-year subsidy amount for "coal-to-electricity"

City	Initial investment subsidy for each household / yuan	Operating cost subsidy for each household / yuan	Subsidy period	3-year total subsidy amount / yuan	3-year total subsidy for each household /(yuan /100 m^2)

Baoding				13400	134
Hengshui		0.2 yuan /(kW·h)×10000 kW·h=2000 yuan		13400	134
Cangzhou				13400	134
Shijiazhuang	7400	First year: 0.2 yuan /(kW·h)× 10000 kW·h=2000 yuan Second and third year: 0.12 yuan /(kW·h)×10000 kW·h=1200 yuan	3	11800	118
Langfang		0.12yuan/ (kW·h)×10000 kW·h =1200yuan		11000	110
Handan				11000	110
Xingtai				11000	110
Tangshan	5550			9150	91.5

5.2 Build demonstration projects of geothermal heating in rural areas

Taking factors such as resources, subsidies, thermal properties of rural houses, per capita disposable income of rural residents, and heating costs into account, we divide the areas of promoting household ground source heat pump and medium-to-deep geothermal heating into three categories (Tables 9-10). It is recommended to give priority to the construction of household ground source heat pump demonstration projects in Class I distributed rural houses with high government subsidies for "coal-to-electricity", high residents' disposable income and good thermal performance of rural houses; give priority to the construction of medium-to-deep geothermal demonstration projects in Class I concentrated rural houses with high heating costs, high disposable income of residents. Through building demonstration projects, promote the high-quality development of geothermal heating in rural areas.

Table 9: Classification Table of Distributed Rural Houses

	Government Subsidy /(Yuan/m^2)	Per Capita Disposable income of rural residents /yuan	Heat Index/(W/m^2)	Strategies
Class I Distributed Rural Houses	> 100	> 15000	< 50	Build demonstration projects, Fast promote
Class II Distributed Rural Houses	50~100	13000~15000	50~100	Steady Promote
Class III Distributed Rural Houses	< 50	< 13000	> 100	Hold off

Table 10: Classification Table of Concentrated Rural Houses

	Resource Condition	Government Subsidy/(Yuan/m^2)	Heating Costs/(Yuan/m^2)	Per Capita Disposable income of rural residents /yuan	Strategies
Class I Concentrated Rural Houses	Favorable areas	> 100	> 22	> 15000	Build demonstration projects, Fast promote
Class II Concentrated Rural Houses	Relatively Favorable areas	50~100	18~22	13000~15000	Steady Promote
Class III Concentrated Rural Houses	General areas	< 50	< 18	< 13000	Hold off

5.3 Increase the initial investment subsidy of geothermal heating

Geothermal heating has the characteristics of high initial investment and low operating cost. It is a typical clean heating method of "supplementing the initial investment and not supplementing the operation costs". It is recommended that the government introduce subsidies for geothermal heating. For shallow geothermal energy, it is recommended to adjust the subsidy structure and increase subsidies for equipment purchases. First, subsidize part of the cost savings from grid upgrades and transformations to equipment purchases; secondly, subsidize part of the savings in operating costs to equipment purchases. Through the optimization of subsidies, we will cultivate high-quality enterprises and better promote clean heating. For medium-to-deep geothermal heating, it is recommended to introduce a subsidy policy for coal to medium-to-deep geothermal heating. The subsidy is 50 yuan/m^2 for Class I areas, and 100 yuan/m^2 for Class II areas.

6. CONCLUSIONS

1.Household ground source heat pump has high heating efficiency, low energy consumption, and low heating operation cost, which is suitable for promotion in distributed rural houses. The operating costs of air source heat pump, gas wall-hung boiler, biomass fuel furnace and carbon crystal plate heating are 1.4, 1.97, 2.23 and 3.88 times respectively of ground source heat pump. Although the equipment purchase cost is high, it is not higher than the upper limit of 374.46 yuan/m^2.

2.The medium-to-deep geothermal heating is clean and environmentally friendly, has zero carbon emissions, and has low operating costs, which is suitable for promotion in concentrated houses in rural areas. Meanwhile, China's rural areas are rich in geothermal resources. "2+26" cities and Fenwei Plain 11 cities have extensive development of sedimentary basin-type geothermal resources, which highly overlap with the clean heating areas in the north and can support clean heating in rural areas.

3. Resource conditions, government subsidy, per capita disposable income of rural residents, thermal performance of rural houses and heating costs are the factors that affect the promotion of geothermal industry in rural areas.

4. Commence the work of energy-saving renovation of distributed rural houses and strengthen the insulation of building walls, doors, windows, and roofs can effectively reduce the operation cost of clean heating and good for the promotion of various clean heating methods. It is recommended to build household ground source heat pump heating demonstration projects in energy-saving distributed rural houses with high government financial subsidies and high residents' disposable income; to build medium-to-deep geothermal heating demonstration projects in the concentrated new rural areas. Geothermal heating has the characteristics of high initial investment and low operating cost. It is recommended that the government formulate a subsidy method that conforms to the characteristics of geothermal heating, optimize the subsidy structure of household ground source heat pumps, and add some pipeline network construction and operating cost subsidies to equipment purchase costs; and issue subsidy policies for medium-to-deep geothermal heating.

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