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Research on Multi–Energy Complementary Energy–Saving Technology for Rural Houses in Northern China

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Summary

Combining with the construction of new rural areas in China of how to solve the problems that not cold in the cold season and not hot in the hot summer in rural houses, effectively improving the living environment of farmers has always been a hot issue of concern to the government. The paper proposes a construction technology that uses double insulated cavity EPS module as a wall material infused with reinforced concrete in the middle for rural houses in the north, which effectively preventing the heat loss in winter and heat flows into houses through the walls in summer. Using the heat energy of the solar water heater and the indoor lumbosacral or floor tiles or the pebble layer under the floor to form a heat storage system to realize the daytime heat storage and heating at night. Use infrared heating soft board as the energy conversion carrier which is heated by household power supply in winter and snowy days. The fusion of two heat storage technologies forms a new scheme for multi–energy complementary heating system in rural houses. The clean energy solar photovoltaic cell is used as the heating power source, and the photovoltaic power generation is used to realize the winter power supply heating and the summer grid–connected power generation to realize the rural residential micro–grid heat and power supply system. After several years of applied research, when the minimum ambient temperature is below 25°C, the indoor average temperature is higher than 18°C, and the underground cold air circulation in the hot summer season can reduce the indoor temperature by 2~4°C, which realizes significant results in energy saving, environmental protection and insulation. The study explored a new way for the construction of new rural areas and the creation of a harmonious environment for rural energy–efficient green residential buildings.

Keywords: Rural house in northern China, Double insulated cavity EPS module, Multi–energy complementary heating system, Micro–grid cogeneration system

1. Introduction

China has a vast territory. Compared with other countries with the same latitude, the cold winter and summer heat are very prominent. With the development of economy and the improvement of people's living standard, people's requirements for the comfort of building environment are getting higher and higher. For the traditional non–heating areas in China, even in the south of the Yangtze River, many new buildings have already used heating equipment, so lately the growth rate of heating energy is obviously higher than the growth rate of energy production in China. China is a large agricultural country, and the rural population accounts for about 60% of the total population. The average actual heating coal consumption per square meter of Beijing rural residential buildings in 2012 was up to 33.5kg of standard coal, 2.7 to 4 times the standard of urban building heating energy consumption, and 2–3 tons of coal for heating each household. Rural heating coal accounts for a large proportion of the total amount of heating coal in the country. Heating coal in rural areas is not only a heavy economic burden for farmers, but also the main source of environmental pollution in rural areas. In recent years, China's northern rural areas have made great progress in the utilization of renewable energy, especially the application of straw vaporization technology in rural areas, which has been favored by farmers. However, the straw vaporization only solved the problem of the farmers' cooking, but the heating problem of 5 months in winter in the north of China is still a plagued by the farmers from generation to generation. The high cost of heating equipment and fuel has made farmers unbearable. They have been suffering from cold winter and hot summer, and have not lived comfortably. It is always the dream of the common people to live in a house as comfortable as the city building.

2. The construction and energy consumption characteristics of rural housing in the north of China

2.1 The construction characteristics of rural housing in the north of China

(i) Low level of construction

Because of the weak technical strength of rural residential construction, the lack of overall design, and the lack of appropriate building materials, the residential building system can not be systematized and the complete set of technology for housing is totally at a disadvantage. Even in a situation where there is no alternative, it often becomes a "colony" for cities to transfer backward materials and technologies.

(ii) Poor environmental quality

Some small towns attach great importance to the construction of residential buildings and invest heavily.

However, the construction of basic designs can not be synchronized, such as the improvement of outdoor environment, sewage treatment and collection and waste discharge. Therefore, it can not meet the needs of the people. Under the influence of these factors, the scene of "indoor modernization and outdoor dirty disorder" has been formed, which has caused serious pollution to the living environment. In addition, heating mainly uses coal, straw and other materials, which produce a large amount of carbon dioxide, sulfur dioxide and other gases into the air. At the same time, a large number of coal ash and cinder pollute the environment.

2.2. The energy consumption characteristics of rural housing in the north of China

(i) The amount of heat lost in the unit building space of rural residential is large. There are residential buildings is three times greater than that of urban buildings.

(ii) The energy consumption ratio of northern rural areas is the highest in winter heating energy consumption, followed by cooking energy consumption. Rural heating in winter mainly burns fuel such as coal and straw, and uses traditional Kang to store heat. Some of the heat energy is dissipated through the chimney to the air. Therefore, the efficiency of energy utilization is low.

(iii) In the same area, heating time in rural areas is longer in winter, and the longest heating time in rural areas is 25% higher than that in urban heating. This is because the urban microclimate is 2~3 degrees higher than the actual temperature in the countryside, and the mountain area is much worse. In addition, the heat loss of the unit space is large and the energy utilization efficiency is low. Therefore, the energy consumption of the rural residential buildings is 2.7 to 4 times the standard energy consumption of the urban building heating.

The walls of urban buildings are not cold. Therefore, under the same building area, the heat loss of rural is more.

3. Northern rural residential buildings and multi–energy complementary integration technology

3.1. Foundation insulation and freezing technology

Foundation insulation is a very important part in north rural residential buildings. The technology of ground insulation and freezing can ensure that the indoor and outdoor frozen soil layer can keep the indoor temperature from loss in winter and extend the service life of the building foundation. In the outside of the foundation, the insulation material shall be not less than 50 mm thick, and the perforated material shall be expanded polystyrene (EPS) or graphite polystyrene (SEPS). The depth of the thermal insulation material underground should be greater than the depth of the local frozen soil.

3.2. Double insulated cavity EPS module wall technology

The double–insulation cavity EPS module is used as a wall material (flame retardant B1 type), and reinforced concrete is poured in the middle. After the concrete in the cavity is solidified, it is integrated with the template to provide internal and external thermal insulation. Double insulation cavity EPS template with the function of shear wall template, the wall thermal resistance value is 5.5 times of the red brick wall thermal resistance value, as shown in Table 1. Fig. 1 shows a double insulated cavity EPS module.

Table 1. Thermal conductivity and resistance of red brick wall and EPS module

Material Name	Material Thickness, mm	Thermal Conductivity, W/(m°C)	Thermal Resistance, m²°C/W
Red brick	370	0.81	0.457
EPS module	40+40	0.032 7	2.446
Reinforcement Concrete	120	1.74	0.069

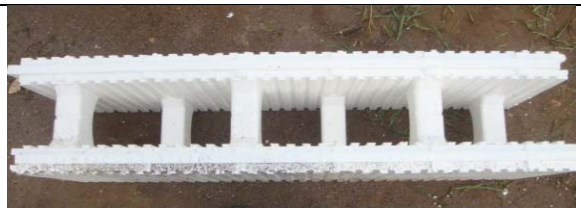
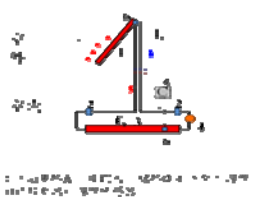


Figure 1. Double insulated cavity EPS module

3.3. Solar water heater heat storage system

The solar water heater heat storage system uses water as a carrier to heat the indoors by storing heat during the day and releasing heat at night. When the temperature of the water in the solar water heater collector tube is 5°C higher than the water temperature in the water pipe of pebble layer in the indoor ground, the automatic water circulation system sends hot water into the indoor hot water pipe for heat exchange with the pebble layer. Solar water heater heat storage system is shown in Fig. 2.



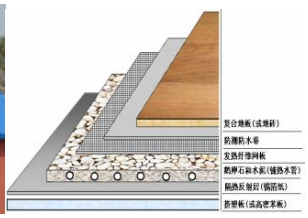


Figure 2. Solar water heater heat storage system

3.4. Far–infrared heating plate geothermal complementary technology

The far–infrared heating fiber soft plate takes 220V household electricity as the energy source, through the form of infrared radiation, electrical energy is converted into thermal energy, which is complementary to indoor heat when there is no sunlight on cloudy and snowy days in winter. Carbon fiber

heating can be laid under floors, floor tiles, or waist–kangs, as shown in Fig. 3.

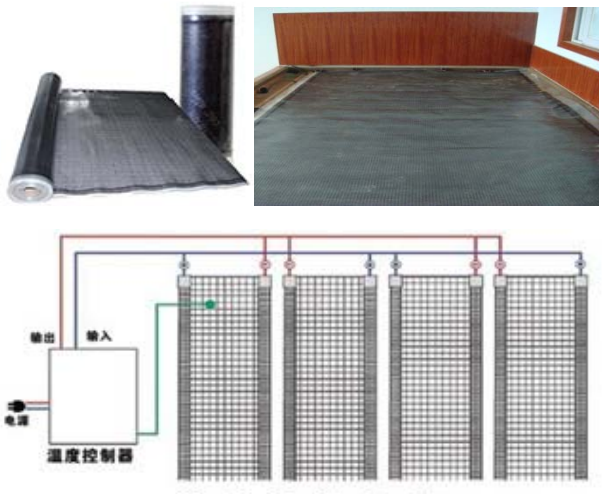


Figure 3. Far–infrared heating plate geothermal complementary technology

3.5. Household type micro–grid heat–electricity combined system

3~5kW photovoltaic cells are installed in residential buildings, which can supply power and heating in winter and grid connection in summer by power generation. Rural residence changes from the energy consumption type housing to the energy output type housing, as shown in Fig. 4.

Figure 4. Household type micro–grid heat–electricity combined system

3.6. Insulation technology of using PE outside the window and attached to the window

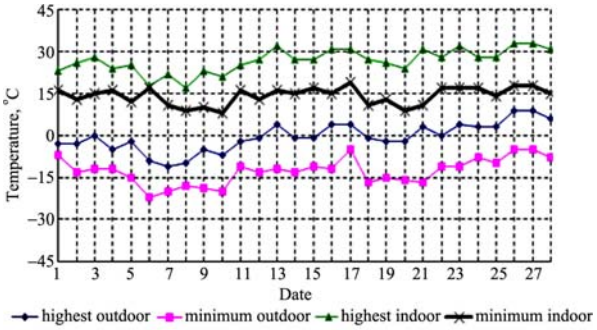
According to the data, 70% of indoor thermal energy in winter losses from windows. By the test at 6 a.m. on January 28, 2015 outside the laboratory of two glassy cavity structure window (At that time, the indoor temperature was 18°C, and the outdoor temperature was –22°C.), the left window has plastic insulation curtain, the right window is not, and the far–infrared imaging temperature of the outdoor show that the effect of energy saving is 19%. Insulation technology of PE bubble film which is attached to the window, the minimum outdoor temperature is –16.3°C, the average temperature of the inside bubble film is –9.4°C, the average temperature of the free bubble film is –8.0°C, and the energy saving effect is 14.9%.

3.7. Control technology of indoor cold and hot environment

Indoor temperature regulation in summer using underground atmospheric temperature gas, the principle is to exchange underground air at room temperature by embedding underground heat and cold exchange pipes. The use of underground normal temperature air in hot summer can reduce indoor temperature by 2°C to 4°C. If the indoor temperature reaches 28°C, the cooling cycle system starts and stops running when the temperature is equal to the room. It runs intermittently for 10 minutes, and the indoor temperature is out of operation under the temperature of below 25°C.

4. Application effect and demonstration project

Since the project implementation, there are more than 100 typical demonstration technologies for rural residential buildings in North–east China, such as Inner Mongolia, Jilin and Liaoning provinces. Fig. 5 shows the indoor and outdoor temperature variation of using water heater in winter. When the lowest outdoor temperature is –22°C, the average indoor temperature is 20.5°C, and Fig. 6 is the engineering demonstration scene.



Temperature, °C	Highest	Minimum	Average
outdoor	9	–22	–15.5
indoor	33	8	20.5

Figure 5. Temperature change curve of indoor and outdoor

Figure 6. Project demonstration scene

5. Conclusion

In the past, there were 3~4 tons of coal for household heating, 800RMB per ton and 3 000RMB for a year. It was calculated by 2.62 tons of carbon dioxide per ton of high quality coal, and a peasant household cut nearly 10 tons of carbon, 400kg of coal ash and 1 tons of domestic waste. But in the new house of multi energy complementary, the farmers have no chimneys, no emissions, no pollution, in addition to the waste of living garbage. Each farmer transforms from energy consumption into energy output type housing through grid connected photovoltaic power generation.

From the angle of stimulating domestic demand in China: the average residence of each peasant household is calculated by $100m^2$, and there are more than 2.4 billion rural households in the whole country. According to the data, the new and rebuilt residential households in the rural areas reach 5% to 6% each year. According to 5%, 10 million rural residential buildings are built per year in the north of the country. If 50% of them are implemented according to the project, the domestic demand will be promoted by 500 billion RMB per year, and the domestic demand of 60 billion RMB is pulled every year in the solar energy water heater industry.

It will stimulate the domestic demand of 110 billion RMB in the photovoltaic battery industry, and at the same time, promote the domestic demand that the relevant enterprises can pull up to 700 billion RMB annually. This project has a great potential to promote my domestic demand.

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