Journal of Modern Agriculture
Volume 7, 2019, PP. 36-44

Study on the Application of Energy-Saving Materials in the Existing Farm Houses in Northern China

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Abstract

For a long time, the architectural characteristics of rural areas in northern China are large occupation of land, low level of construction technology, lack of scientific nature, neglect of the most basic thermal performance and comfort requirements of buildings, low energy utilization ratio, resulting in low land utilization rate of agricultural houses, poor thermal insulation performance, high energy consumption and low comfort, which violate the principle of sustainable development of energy conservation. Therefore, in order to improve the quality of life of farmers to conform to the sustainable development of energy, this paper puts forward the research and transformation of the existing agricultural houses, the scientific formulation of the planning system of agricultural houses, and the promotion of building energy saving and the development of energy-saving buildings in rural areas of the north according to local conditions. It is decided to study and transform the energy-saving materials and the space of agricultural houses in northern China, so as to create an indoor environment for farmers in northern China, which is not only comfortable, but also does not cause a large amount of energy consumption.

Keywords: Energy Saving Transformation; Enclosure Structure; Thermal Performance; Agricultural House Space

1 THE MEANING OF EXISTING FARM HOUSE

The energy saving transformation of existing agricultural houses refers to the activities of energy saving transformation of existing buildings, such as enclosure structure, heating system, heating and refrigeration system, lighting equipment and hot water supply facilities, which do not meet the mandatory standards of energy saving in civil buildings. " During the 12th five-year Plan period, more than 400 million square meters of heating metering and energy saving transformation of existing residential buildings in northern heating areas have been completed, and the energy saving transformation of existing residential buildings in hot summer and cold winter and hot summer and warm winter areas has been completed. The main contents are the thermal insulation transformation of exterior wall, roof, outer doors and windows, the transformation of heating system household heating metering and room temperature control, the renovation of buildings, the improvement of function and the comprehensive energy saving transformation of using renewable energy, etc.

2 THE HEAT TRANSFER CHARACTERISTICS OF THE ENCLOSURE AND THE ENERGY-SAVING STUDY OF THE HOUSE

The rural construction in the northern area of China should be adapted to the dual needs of the daily living and the production of the agricultural and sideline products, and the building types of the residents are mostly single-family, double-household and multi-household parallel construction types. For a long time, most of the rural buildings in our country are of individual construction, the peasants will be arbitrarily constructed, and the construction of the rural areas is lacking in planning and design, so the functional division of the buildings is unreasonable and the land is

wasted. During the construction of the house, due to the limitation of the technical and construction conditions and the restriction of the economic conditions, some backward building materials are used in the construction of the farmers, and the design of the enclosing structure still adopts the traditional method, so that the energy consumption of the building is large, and the energy-saving is not favorable. Compared with the traditional courtyard, the overall conformability of the existing courtyard is gradually reduced, the energy-saving is very negative, and the comfort degree of the indoor thermal environment is influenced.

2.1 Wall and Thermal Insulation Materials

The main forms of external wall of rural traditional residence are 37 clay brick wall, internal plastering or putty plastering, the decoration of outer wall is different. Sintered non-clay porous brick is a common energy-saving material for agricultural house construction at present. compared with solid brick, sintered non-clay porous brick reduces the consumption of raw materials, reduces the weight of wall and enhances the performance of heat preservation and heat insulation. Autoclaved lime sand brick is a kind of load-bearing brick, which is of higher quality than sintered brick, so it is more suitable for load-bearing wall of multi-story mixed structure building because of its sound insulation and heat storage capacity. Ordinary concrete small hollow block is a new type of energy-saving wall material, which can be used as load-bearing and non-load-bearing wall. Autoclaved aerated concrete block is mainly used for external filling wall and non-load-bearing inner wall. The following are the suitable external wall insulation selection forms for rural housing in cold areas of northern China, as shown in Table 2-1.

TABLE 2-1 EXTERNAL WALL TYPES AND THERMAL PERFORMANCE INDICATORS

Name	External heat preservation of sintered non-clay porous brick	Autoclaved lime-sand brick external thermal insulation	External heat preservation of ordinary concrete hollow brick	Autoclaved aerated concrete brick external heat insulation
Wall structure	20mm thick mixed mortar 240mm thick porous brick cement(-sand) mortar flat bed adhesive heat insulating material 5mm thick crack resistant mortar alkali resistant glass fiber mesh cloth exterior finish	20mm thick mixed mortar 240mm thick autoclaved lime sand brick cement(-sand) mortar flat bed adhesive heat insulating material 5mm thick crack resistant mortar alkali resistant glass fiber mesh cloth exterior finish	20mm thick mixed mortar 240mm thick aerated concrete brick cement(-sand) mortar flat bed adhesive heat insulating material 5mm thick crack resistant mortar alkali resistant glass fiber mesh cloth exterior finish	20mm thick mixed mortar 240mm thick autoclaved aerated concrete brick cement(-sand) mortar flat bed adhesive heat insulating material 5mm thick crack resistant mortar alkali resistant glass fiber mesh cloth exterior finish

The thermal insulation performance of the wall is autoclaved aerated concrete brick building, sintered non-clay porous brick building, concrete hollow brick building, solid clay brick building, autoclaved lime sand brick building. The thermal load of autoclaved aerated concrete brick wall changes smoothly, and the thermal stability is the best. The type and thickness of suitable heat preservation materials need to be considered comprehensively according to the local economic level and climate characteristics. On the one hand, the heat preservation materials with good thermal insulation performance and reasonable price should be adopted, on the other hand, the properties of cold wind resistance, thermal stress resistance and so on should be considered to ensure that the comprehensive properties match with the life span. The main thermal insulation materials are polystyrene foam board (EPS board), rock cotton, slag, rice husk sawdust licorice and so on. Polystyrene foam board (EPS board) has good thermal insulation performance, which is not only suitable for the external heat preservation of the external wall of the new building, but also suitable for the energy saving transformation of the old building, and can also be used for roof insulation. The external tile should be strengthened. Rock cotton external heat preservation system has the characteristics of

good environmental protection, good sound insulation and sound absorption, non-combustion, high grade of heat resistance and fire prevention, etc. It can be used in building energy saving wall, roof, ground insulation, wall using rock cotton board, roof using rock cotton felt, ground using rock cotton brick. The external insulation of rock cotton exterior wall is widely used in Europe and North America, but the main problem of rock cotton insulation is that the thermal insulation performance still needs to be improved, and the construction performance is poor. The thicker the thickness of the insulation material is, the better. When considering the thermal insulation performance of the wall, the economic benefit should also be considered. The thermal insulation performance of thermal insulation materials is mainly considered in cold regions. The parameters of commonly used thermal insulation materials are shown in Table 2-2.

TABLE 2-2 PERFORMANCE OF COMMON INSULATION MATERIALS

Heat insulating Material	Dry density ρ_0 (kg/m^3)	Heat conductivity W/(m·k)	Specific heat J/(kg.k)□	Merit	Shortcoming
EPS board	30	0.042	1380	The price is moderate, the use efficiency is high, and the construction is convenient. It's cheap and takes a long time to use.	Easy to aging, poor freeze-thaw resistance Easy to moisture, not environmentally friendly, rock cotton contains harmful substances to the human body
Rock wool board	70	0.054	1220		

Through market research,40 mm thick EPS thermal insulation board 40 Yuan/ kWh (including labor), it can save 5921.27 kWh each year. If the electricity price is calculated according to 0.52 yuan/ kWh, the annual saving is RMB 3079 Yuan, the payback period is 1.7 years, and the 50 mm thick rock wool insulation board is 45 Yuan/ year (including labor), and the payback period is 1.93 years. In this paper, a 40mm thick EPS insulation board is recommended for external wall insulation. because the heat of the external wall is about 25-28% of the total energy consumption of the whole enclosing structure, the thermal insulation board is not only used in the design of the outer wall of the northern rural building in the cold area, but also the external wall material of the building can be reasonably selected according to the existing raw materials, And the energy-saving bricks such as hollow bricks or concrete hollow small blocks are extended. At the same time, the construction measures can be selected flexibly at the time of construction, and the material (rice husk, wheat straw, etc.) which is easy to be obtained in the rural areas is used as the external wall heat-insulating material, so that the external wall can be well insulated, and the concept of energy sustainable development is met.

2.2 Ground Heat Preservation

The heat of heat transfer through the enclosure that is in contact with the ground is large, especially in cold areas, in low-rise residential or basement-based buildings. The surface temperature is low, and if the ground does not take thermal insulation measures, the indoor heat can be drained from the ground in a conductive way, and the indoor environment can be deteriorated. Therefore, it is necessary to take the heat preservation measures on the ground, because the ground has the infinite heat storage capacity, the thermal stability is good, it is also a design direction of the modern green building. As the heat preservation and energy-saving awareness of the farmers is enhanced, the heat-insulating layer is arranged on the ground of the newly-built housing in the rural areas, and most of the heat-insulating materials are slag with lower manufacturing cost, and the heat-insulating materials such as corrugated plates are used, but the cost is high, So the low-temperature floor radiation heating system is also a good heat preservation energy-saving measure. See Table 2-3 for data on the structural form of non-thermal insulation measures taken by the ground and the thermal insulation of the slag, respectively.

TABLE 2-3 GROUND STRUCTURE

Name	No heat preservation	Bira nest heat preservation
Ground tectonic layer	20mm thick cement mortar 60 mm thick plain concrete rammed earth	20mm thick cement mortar 60mm concrete cushion 500mm thick slag cushion rammed earth

Compared with the uninsulated ground, the energy consumption of the whole year is 41.75 kWh/ min, and the energy saving rate is 24.5%.

2.3 Roof Insulation

Areas, cast-in-place reinforced concrete can also be used as the roof structural layer, and the thermal insulation material is selected from expanded perlite, polystyrene composite material, glass wool and the like. According to the current national standard, the design standard for building energy-saving in rural areas is GB/ T50824-2013, and the heat transfer coefficient of the roof in the cold area is 0.5W/（㎡.K）.The table below is the structural hierarchy of the roof in the northern rural areas.

TABLE 2-4 OF STRUCTURE LEVEL

Name	Wooden house slope roof
Roof structure	1- wooden house slope roof 2- sandalwood strips 3- plank support 4- 20mm thick straw roof board 5- 20mm thick cement mortar 6- 30mm thick EPS insulation plate 7- 20mm thick lime mortar 8- Red roof tile

The roof of rural residential buildings in northern China is mainly divided into slope roof and roof. Because of its limited ability to bear the load, wooden roof is usually used as thermal insulation ceiling under wooden roof frame, which is the most common form of roof thermal insulation structure. Thermal insulation materials should choose traditional light bulk materials, such as sawdust, slag, etc., EPS or XPS plate insulation materials can also be used, thermal insulation ceiling can effectively prevent the indoor from being lost directly through the roof, and can also prevent cold air from entering the room directly through the roof crevice. Reinforced concrete roof can directly lay insulation layer on top to achieve the purpose of energy saving, but the durability of waterproof layer is high. Another transformation method of reinforced concrete roof is "flat" to "green", that is, the basic structural level of transforming roof into planting roof planting flat roof includes: structural layer, insulation layer, slope (leveling) layer, ordinary waterproof layer, root piercing waterproof layer, protective layer, drainage (storage) layer, Filter layer, planting soil layer and vegetation layer, etc. According to the climatic characteristics, roof form, plant species and so on, the roof structure level can be increased or decreased.

2.4 Doors and Windows

The building energy saving in the rural areas of northern China mainly considers the thermal insulation characteristics of the enclosure structure in winter, in which the air tightness of doors and windows should also be paid attention to, and it is not suitable to exchange too much air with the outside world. For example, the outer doors in rural areas will be frequently opened, which will inevitably lead to the loss of indoor heat, so heat preservation measures should be taken at the outer doors. Considering that the economic conditions in rural areas are no more

than those in cities, the selection of doors and windows can not be consistent with the criteria of urban selection, which needs to be considered comprehensively in the light of the local economic situation, climate characteristics and the relevant codes of Energy Saving Design Standard for Rural Residential buildings. In the reconstruction of the outer window of the existing farm house, it is a simple and easy operation to replace the single-story outer window with poor heat preservation capacity and poor sealing performance directly into the energy-saving outer window with good thermal insulation performance. The material of window frame should choose the composite window frame with small thermal conductivity and good heat preservation effect, and the plastic steel treated by broken heat treatment is more suitable and the cost is acceptable. Double hollow glass should be used in glass. According to the current national standard "Rural Residential Building Energy Saving Design Standard" GB/T50824-2013 and "Civil Building Energy Saving Design Standard" JGJ26-95, the outer window of rural housing in cold area, the limit value of heat transfer coefficient of the outer door and the window wall ratio in different directions are shown in Table 2-5.

TABLE 2-5 LIMIT VALUE OF HEAT TRANSFER COEFFICIENT OF OUTER WINDOW AND OUTER DOOR

Cold areas exterior window	Southing	North	East-west	Exterior door
Limit value of heat transfer coefficient	2.8	2.5	2.5	2.5
Window wall scale	0.35	0.25	0.3	—

At present, the northern rural residential windows are mainly plastic windows and aluminum alloy windows, glass is mainly hollow glass, Low-E glass. The door is mainly plastic door, wooden door, metal insulation door, aluminum alloy door, door and window opening mode is mainly flat. The heat preservation measures of the outer window include the installation of insulation board or curtain, and the heat preservation measures of the outer door can add cotton door curtain, door bucket and so on. And reasonable determination of window-wall ratio is conducive to summer ventilation and winter heat preservation, save refrigeration, heating energy consumption, so if the window opening area has met the indoor lighting requirements, the window opening should not be increased, for agricultural houses with too large window-wall ratio, it can be properly reduced.

3 Existing Farm Houses Are Not Conducive to Energy Conservation

Through the investigation of some villages, it is concluded that the following problems are common in the existing agricultural houses in the north:

(1) The outer envelope (outer wall, outer door and window, roof), on the one hand, is poor in heat preservation ability due to the lack of thermal insulation measures, and the indoor surface temperature is lower than the dew point temperature in the room, It is easy to dewing and mildewing; on the other hand, due to the large temperature difference between indoor and outdoor in winter, the air-tightness of the outer envelope is poor, and the air permeability is serious, so that the heating energy consumption in the winter is high, and the heating effect is not good.

(2) There is a lack of greening and shading in the courtyard. Due to the lack of greening and shading in summer, the courtyard in northern China will be exposed to strong solar radiation, coupled with the fact that most of the ground is cement ground and has strong heat storage capacity, so it will feel very hot in summer in the courtyard.

(3) The utilization of renewable energy (solar and methane) in rural areas is insufficient. In the rural areas, the utilization of the solar energy should be vigorously promoted, and the local straw and domestic garbage can be fully utilized in the rural areas to establish a good biogas system and increase the utilization of the biogas to achieve the purpose of making full use of natural resources.

4 Study on Energy Saving Transformation of Existing Agricultural Houses in North China

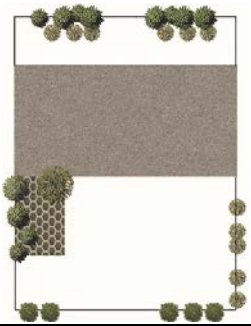
4.1 Reconstruction of Existing Rural Residential Houses

The floor laying and greening of the courtyard, the selection of suitable floor tiles, and the improvement of the environment of the courtyard by plants; the single space of the building is optimized to reduce the heating energy consumption by adding additional sunlight to reduce the heating energy consumption; the reasonable thermal insulation structure method is used, and the materials suitable for the thermal insulation performance are selected to increase the thermal insulation measures of the enclosure structure and improve its thermal performance. Increase the efficiency of solar energy and biogas utilization, optimize the energy structure in rural areas.

(1) The courtyard of the courtyard is reconstructed, and the courtyard of the modern agricultural house has abandoned the previous brick laying, and the cement ground is used in a large amount, and the water permeability of the original paving is lost. The traditional courtyard is paved with masonry, has good water permeability, does not cause water in the courtyard, and a part of the rainwater can penetrate into the surface through the gap of the brick and stone, and the internal environment and the humid environment of the farmhouse courtyard can be wet to adjust the climate in the hospital when the water is slowly evaporated; And a part of the rainwater is discharged out of the courtyard along the drainage ditch. The modern agricultural house has passed through the cement-hardened courtyard, although it is convenient to clean and clean, on the one hand, the rainwater is accumulated, and on the other hand, the effect of regulating the environment for moistening the air is lost, so the courtyard of the modern agricultural house should be a floor tile with strong water permeability, Inherit the way of the traditional courtyard to improve the overall environment of the yard.

(2) The transformation of the garden greening, the courtyard is the important role in the rural residence, and provides the production and living space for the residents. In the design of the modern courtyard energy-saving design, not only the mode of the courtyard is modified, but also the greening design of the courtyard should be optimized. the tree and the shrub are planted in the courtyard, and the temperature of the courtyard is adjusted by using the seasons, so that the hot and cold winter conditions in the summer can be effectively improved, the deciduous trees and the shrubs can be planted in the courtyard, the sunlight can be blocked in the summer, and the lighting of the building is not influenced in the winter, The plant plays a role in regulating the micro-environment in the building. (See Table 4-1)

TABLE 4-1 SCHEMATIC DIAGRAM OF GREENING LAYOUT OF AGRICULTURAL HOUSES IN THE NORTH OF CHINA

area	north	Planting map	main point of planting
			1.Planting trees in the south can shade the sun in summer, and the leaf lag in winter does not affect the lighting in the south. 2. Growing evergreen tree species in the north Winter weather.

4.2 Reconstruction of Existing Farm House Space

The energy-saving strategy of building single design is an important part of the current energy-saving design of agricultural houses. Due to the different characteristics of buildings in different areas, the appropriate energy-saving means are also different, mainly living space bedrooms, the living room is concentrated in the south lighting of the main room, in order to maximize light, the north side of the auxiliary room including kitchen, storage room, bathroom, can reduce the impact of winter northwest wind on the main room. Play the role of heat preservation and heat storage, improve the quality of residential products, reduce heating energy consumption. Moreover, there are

many eaves expanding outward in the main house of the northern farm house to form an outer porch, which provides favorable conditions for the use of additional sunlight for heating described below.

(1) Front yard agricultural house space: according to the construction age, the plane layout is also quite different, most of the agricultural house use space is distributed layout, at the same time, in order to obtain larger courtyard space, households generally only arrange auxiliary rooms on one side of the courtyard, so the single plane of the building is usually "L" shaped layout, the style is that the eaves go out to pick out a certain distance to form an outer porch, usually 1.2 m～1.5 m. In this form, the south corridor can be made into a closed space, so that the outer corridor can be transformed into a sunlight room (see Table 4-2). Most of the plane layout of the farm house built after 2010 is a single building, the layout is also changed, and the layout is relatively compact. Therefore, the southern corridor can be transformed into an additional sunlight room (see Table 4-3), which can allow the sun to shine through glass to produce "Greenhouse Effect" and raise the indoor temperature. And do not let heat lose, can be used as a rest space for households in rainy and snowy weather, and plant flowers and plants in the sun to beautify the environment. Therefore, it can effectively use its winter heating, so as to reduce heating energy consumption. In summer, the window sash between the sun will be opened, and the window can be closed at the top of the house in winter to put the sunshade cloth on the sunshade cloth, which provides an outdoor space with sun shade and air circulation. At the same time, in order to increase the utilization efficiency of solar energy, solar collector is installed on the slope roof of two agricultural houses, which can solve the problem of domestic hot water demand, fully realize the purpose of energy saving and emission reduction, and ecological and environmental protection.

TABLE 4-2 COMPARISON BEFORE AND AFTER THE RECONSTRUCTION OF FRONT YARD FARM HOUSE

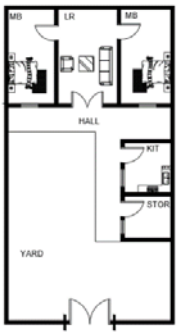
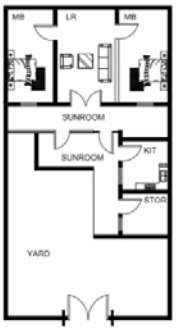
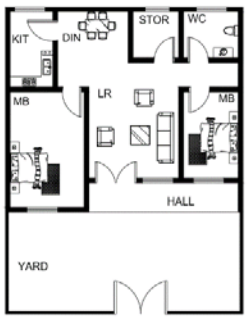
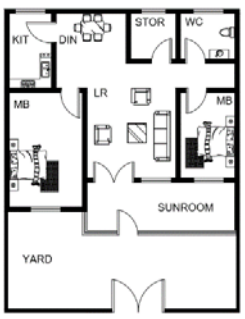
	Before transformation	**After transformation**
ichnography		

TABLE 4-3 COMPARISON BEFORE AND AFTER THE SECOND TRANSFORMATION OF FARM HOUSE

Before transformation	**Before transformation**
	

(2) Front backyard farm house space: similar to the front yard farm house reconstruction measures, the front yard type farm house only increases the 2m~3m back yard space, the backyard mainly serves as domestic fuel, domestic garbage storage space. In the south part of the main building, the corridor can also be transformed into an additional

sunshine room, which is used as a daily rest space to plant flowers and grass in the sunshine room to purify air and beautify the environment.

(3) Enclosed farmhouse space: because each use room of enclosed farm house is arranged along the periphery of the yard, the courtyard “Tianjing” is formed in the middle of the yard, the yard looks closed as a whole, and the shape of enclosed farm house is relatively large, which is very unfavorable for energy conservation. In order to reduce the shape coefficient and make full use the atrium space, the atrium space is sealed with glass sunroof to form a closed sunlight atrium, which can have a certain heating effect like an additional sunlight room, and can also provide a wider outdoor activity space for residents.

5 Energy sources for Comprehensive Development and Application of Agricultural Houses in North China

5.1 Development and Application of Multi-Energy Complementary Energy-saving Technology

It is not the only way to save energy by improving the thermal insulation of the enclosure structure. There are many other ways. For example, the effective utilization of renewable energy, thermal energy recovery, building shading, configuration and operation and management of building electrical energy-using equipment, etc. In order to implement the State Council's work plan for the sustainable development of energy conservation and emission reduction, the Ministry of Science and Technology, through the National Science and Technology Support Plan, launched the project "Integration and Demonstration of Multi-Energy Complementary Energy-saving Technologies for Rural Residential Houses in the North ", focusing on low-carbon rural residential structures and energy conversion technologies, integration of rural residential energy storage systems, and energy-saving technologies complementary to biomass and solar energy-saving technologies in rural residential buildings in the North of China. In rural residential energy sources, the project initially completed the northern rural residential wind, light energy conversion and energy storage and utilization research. the invention relates to a double-heat-insulation benzene plate wall-based rural residence. In order to solve the problem of new energy utilization in the rural residence in the north of China, a new thought is explored.

5.2 Development and Application of Other Sources Of Energy

In addition, China is also rich in shallow geothermal energy, which can develop and utilize local geothermal resources in rural areas of the north, provide heat source for centralized planning and construction of village and town buildings, and is suitable for centralized hot water supply and heating facilities construction, so as to save fuel use. Some areas of northern rural areas are also rich in wind energy resources, using it to build wind power to supply daily life and lighting electricity, which is convenient and cheap to save electricity.

5.3 Development and Application of Biogas

In the northern rural areas, hot water is also the main energy consumption, so the energy saving of rural buildings should focus on the adjustment of cooking energy structure. Biogas is a kind of clean renewable energy. Biogas construction is combined with seed culture industry. Through the optimal allocation of resources, the economic chain is extended, and the effective recycling of energy is made. Therefore, the popularization and use of biogas is more suitable for the adjustment of rural building energy structure, and can achieve remarkable energy saving effect. However, most of the rural areas in Northeast China use single-household biogas construction, which is often limited by technical conditions, and the biogas production is often insufficient, and the safety is poor. Therefore, it is necessary to make adjustments, taking into account that the residents of the surrounding villages and towns in rural areas are still cultivated traditional crops, and a large number of crop straw and other surplus, most of which are idle and wasted or burned on the spot. It is suggested that high efficiency biogas facilities should be built in rural and surrounding villages, and household biogas digesters should be transformed into medium biogas projects in order to promote the comprehensive utilization of agricultural waste and biogas slurry and make effective use of resources. In addition, biogas slurry and biogas residue can be used as organic fertilizers, which can make biogas facilities have high energy efficiency and reduce environmental pollution at the same time. Biogas can not only be used to solve the

problem of lack of fuel in rural areas, but also can be used for comprehensive utilization of heating and lighting.

5.4 Solar Energy Development and Application

The rural areas of the north have abundant solar resources, the rural clean energy is actively applied, more solar water heaters are made to enter the farmers' families, the promotion and utilization of the solar energy in the rural areas are promoted, and the solar energy comprehensive utilization building is built, The solar utilization device for placing the solar energy on the roof can provide comprehensive application of domestic hot water, heating system and illumination. In particular to the application of the solar low-temperature floor radiation heating system in recent years, and is suitable for application in a non-centralized heating rural building. The solar water heater can also save the conventional energy consumption of daily hot water such as cooking, washing and bathing. Tap water and ground water can be used as the water source of the solar hot water system according to different water supply modes, and the heat collecting plate is installed on the roof so that the solar radiation can be maximally accepted and converted into heat energy.

At present, due to the restriction of economic conditions in the rural areas of northern China, most rural buildings are unable to use energy-saving design, which requires the state and local governments to provide policy and economic support, research and develop cheap energy-saving building materials and energy utilization equipment suitable for rural areas, establish the concept of sustainable development, establish rural building planning and management system, and vigorously promote energy-saving materials in rural areas. Create a healthy and comfortable living environment for the vast number of farmers.

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