International Journal for Housing Science and Its Applications
Publish August 10, 2025. Volume 46, Issue 4 Pages 3584-3596

https://doi.org/10.70517/ijhsa464486a

Research on Natural Resource Recycling Technologies in Housing Buildings Based on Symbiotic Designs

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Abstract At present, there are few kinds of natural resources utilisation in housing buildings and unreasonable ways of utilisation, for this reason, on the basis of symbiotic design concept and the definition of natural resources recycling technology in buildings and houses, solar heating technology and rainwater utilisation technology are introduced. The design of residential solar heating technology is based on thermodynamic model and solar collector, and the design of residential rainwater utilisation technology is based on the design of recessed green space, paved brick floor, and infiltration/drainage integration after completing the design of this technology. Determine the research sample, combined with the corresponding evaluation index, the application of the two technologies designed in the previous analysis. It is concluded that the technology can save 57.86% of heating energy consumption when roof and wall collectors are integrated to supply heating to the building, and its energy-saving effect is particularly significant. In addition, the effect of rainwater use technology on the reduction of residential runoff coefficient is maintained in the range of 30%~50%, which is considerable, and is in line with the principle of sustainable development of natural resources in housing construction.

Index Terms solar heating technology, rainwater utilisation technology, sustainable development, housing construction

I. Introduction

Energy and environment are important pillars for the sustainable development of a country or a society. Due to global climate change, ecological environment deterioration and resource scarcity, countries around the world have attached great importance to energy conservation and emission reduction. Since part of the energy waste comes from the maintenance and use of buildings, it is crucial for architects to fully consider the building type, building volume and climate region, and use reasonable technical means to achieve the integration of housing buildings and regional natural resources symbiosis is a crucial part of the design process [1]-[3].

Housing buildings with symbiotic design maximise the use of natural conditions and create a pleasant and comfortable environment through artificial means, while strictly controlling and reducing human occupation of natural resources to ensure a dynamic balance between natural demand and return [4]-[7]. This dynamic balance is not only reflected in the appropriate methods and materials used in the design and construction of the building, but also in the extent to which it consumes and utilises resources and gives back to nature [8]-[10]. By introducing renewable energy systems into buildings, using environmentally friendly building materials and optimising interior layouts, designers can significantly reduce the energy consumption of buildings and improve the quality of life of occupants [11]-[14]. In promoting the sustainable development of residential buildings, this symbiotic design concept has not only played an important role in the past practice, but also has a broad space for development in the future, which will provide a healthier, more environmentally friendly and more livable living environment and make a positive contribution to global sustainable development [15]-[18].

The main innovation of this project is not to consider solar energy resource utilisation technology alone, but to combine the symbiosis design concept with the research of solar energy resource utilisation technology and rainwater utilisation technology, which is particularly significant in terms of resource utilisation efficiency compared to the single resource utilisation technology. First determine the thermodynamic mathematical model of solar heating, combined with the corresponding heating hardware equipment, the reality of residential solar heating technology design, after the realisation of the technology, from the green space, paving the ground, seepage and drainage integration as a starting point, to complete the design of residential rainwater use technology project. Taking a five-storey residential building in a certain city as the research sample of this project, we set evaluation indexes, combined with evaluation indexes and research data, and analysed the application effect of residential solar heating technology and residential rainwater use technology respectively.

II. Relevant theoretical foundations

II. A. Co-design Core Elements and Key Features

II. A. 1) Core Elements of Symbiotic Design

The research on the sources of symbiotic design has led to a more systematic and accurate understanding of the connotation of symbiotic design. This project proposes that the connotation of symbiotic design for housing architecture should be: a recreation process based on a holistic and moderate attitude, taking the connection as the object of the design process, and realising the harmony and compatibility of housing architecture.

The holistic and moderate attitude is the base of symbiotic design, the connection as the object of the design process is the methodology of symbiotic design, the realisation of the harmony and compatibility between housing buildings and the environment is the goal of symbiotic design, and the process of re-creation is the essence of the design.

It can be argued that the core of the connotation of symbiotic design lies in its methodology, i.e., taking the connection as the object, which is essentially different from other design theories [19]. The connection as the object of the design process means that in the design process, the first thing to grasp the design object is to start from the connection between the relevant elements and factors, rather than focusing on the figurative object. The design process of taking connection as the object needs to be carried out from the levels of identifying connection, analysing connection, constructing connection and dealing with connection. Among them, constructing connections is the core level, and symbiotic design itself is a multi-dimensional construction process based on connections, and constructing connections is the concentrated expression of symbiotic design.

II. A. 2) Key features of symbiotic design

The symbiotic design of housing buildings also has to deal with site, environment, culture, economy and other elements, and involves research, evaluation, planning, decision-making, design, implementation and other links. Symbiotic design can not be separated from the general project to face the situation and factors, so symbiotic design and other design theories have the same and universal adaptability, but the landscape architecture symbiotic design as a design concept applied to the design practice, because of its essential methodological differences, in each link to deal with the various factors associated with the performance of their own design characteristics. In the previous section, the core idea of symbiosis design is to emphasise the connection as the object of the design process, which extends some characteristics in the specific performance of symbiosis design. This project summarises the four main characteristics of symbiotic design, which are clear design hierarchy, innovative design, coordinated and appropriate design, and open-source design intention.

II. B. Technologies for recycling natural resources in building and housing

The construction of residential buildings is inexpensive, and in the process of building residential buildings, attention should be paid to the selection of building materials, as far as possible, mainly local materials, to give full play to the advantages of local resources, and the construction process must be guided by specifications, and should not be constructed only on the basis of traditional experience. In the use of resources, should try to solar energy, wind energy, geothermal energy and other natural resources, reduce the consumption of other resources. Compared with the perfect municipal facilities in the city, rural housing is still relatively backward in terms of water and sewage, waste disposal, etc. This requires us to start from a holistic point of view in the planning and design process of housing, based on the technology of resource recycling, and strive to improve the recycling rate of resources and reduce the emission and discarding of waste. Solar heating technology and rainwater utilisation technology will be described in detail next. They are shown below:

II. B. 1) Solar heating technology

Solar energy has the characteristics of clean and environmentally friendly, non-polluting, rich source, and as a widely distributed renewable energy source, these characteristics are in line with the demand for grade energy in the construction industry, so the use of solar energy in buildings as a clean renewable energy source has become a new field of concern and research for many domestic and foreign researchers and has achieved a rapid development [20]. However, due to the many inherent disadvantages of solar energy, such as relatively low energy density and high cost of collection and utilisation [21]. Therefore, to achieve the purpose of energy saving and environmental protection of energy consumption in the construction industry can only be achieved through the selection of suitable and reasonable solar energy utilisation methods. The performance and application range of this type of utilisation of solar energy is shown in Table 1. As can be seen from the table, the effect of solar thermal utilisation is more satisfactory, with an efficiency of up to 80%. In contrast, solar lighting and solar photovoltaic power generation is not only higher initial investment and lower average efficiency, the highest efficiency are not more than 60%, in addition to solar photovoltaic power generation battery power is unstable, need to be replaced often, the production process requires the consumption of a large number of resources, more serious pollution of the environment. From the above analysis, it can be concluded that in the current use of solar energy, solar thermal technology is the most mature, with high conversion efficiency and low cost. HVAC energy consumption and hot water energy consumption in the building energy consumption occupies a high proportion, accounting for about 60%, and there is a continuing trend of increase. Therefore, in terms of the effective use of resources, solar thermal use is the most reasonable and economical, but also the most promising way to use solar energy.

Table 1: The performance and application range of this use of solar energy

Usage mode	Average efficiency/%	Lifetime/a	Initial investment	Technical maturity	Environmental friendliness	Application range
Solar lighting	0~25	20~25	Height	Height	Height	Lighting
Solar water heater	35~70	0~10	Medium	Height	Height	Hot water
Solar heating	15~40	5~15	Medium	Medium	Height	Heating, Hot water
Solar refrigeration	30~40	0~10	Height	Medium	Medium	Air-conditioning refrigeration
Solar heat pump	35~50	0~10	Medium	Low	Medium	Heating, Hot water, refrigeration
Solar air collector	40~50	0~15	Low	Height	Height	Heating, drying, ventilation
Solar photovoltaic	5~30	0~10	Height	Height	Low	Householdelectricity, lighting, communication, transportation, etc

II. B. 2) Rainwater utilisation techniques

In residential buildings, the roof is the most commonly used rainwater collection surface, in the collection process, not only to take into account what is usually called the roof rainwater collection outside, sometimes should also be combined with the characteristics of the building to consider part of the rainwater on the vertical surface, can be divided into residential rainwater collection and use of the technical principle of the installation of undercove green space, the installation of permeable paving brick floor, the installation of seepage and drainage integrated system.

Among them, we should pay attention to the following issues in the rainwater piping system:

(1) The rainwater collection pipe should be used separately from the sewage drain or vent pipe of the building, and the piping must be set up separately [22].

(2) In order to avoid the mixing of drainage paths of different floors causing overflow of flooding on the ground floor, separate drainage paths should be set up independently for the rainwater collection areas of different floors.

(3) Sweeping outlets should be provided at suitable locations at the ends or turns of rainwater catchment cross-pipes to facilitate cleaning and maintenance.

(4) The inflow of surface water and debris should be minimised or even avoided and it should be ensured that the inspection well facilities in the rainwater pipe system can be easily maintained and cleaned.

III. Study design

Combined with the connotation and characteristics of residential natural resource use technology given in the previous section, this chapter will be designed for building residential solar heating technology and residential rainwater use technology. The detailed design process and operation principle are shown below:

III. A. Residential solar heating technology design

III. A. 1) Principles of operation

The principle of operation as shown in Figure 1, when the collector temperature is greater than 50 ℃, the controller starts to start the pump will be sent to the collector to start heating the water, the resulting water pressure can be the hot water inside the collector into the tank, due to the temperature inside the tank on the high side and the low side of the lower cooling water is sent to the collector to be heated, thus forming a cycle. When the collector temperature is less than 40 ℃, the pump stops working, and a check valve is installed to prevent reverse circulation and heat loss of the collector at night. When the temperature of the water supplied to the thermal storage tank is less than 45℃, the pump can be switched on to carry out the heating cycle. As the heat output of the solar collector varies with time, an auxiliary heater is installed in the system, so that when it is cloudy and rainy or when the solar energy supply is insufficient at night, the three-way valve can be opened and the auxiliary heat source can be used for heating. The heat storage tank is connected to the upper and lower water pipes of the collector for hot water circulation. The capacity of the storage tank is determined according to the amount of hot water required for solar underfloor heating on a daily basis.

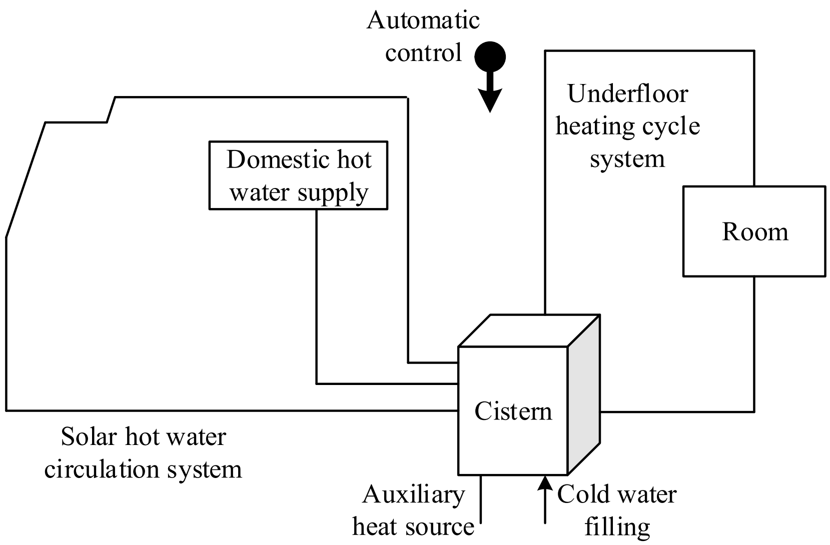


Figure 1: Operating structure

III. A. 2) Solar collector selection

A solar collector is a device that absorbs solar radiation and transfers the resulting heat energy to a heat transfer medium. The three main types of solar collectors currently utilised are flat plate type collectors, U-type all-glass vacuum tube collectors and heat pipe-vacuum tube collectors. And the U-type all-glass vacuum tube is used in this subject, which is described in detail as follows:

U-tube vacuum collector consists of U-tube, vacuum tube, ribbed frame, etc. U-shaped metal heat absorbing tube is coated with selective absorption coating on its surface and placed at the bottom of the glass tube, and the bottom half of the inner wall of the glass tube is coated with reflective material to produce the concentrating utility, which has an excellent effect of concentrating light.

III. A. 3) Construction of thermodynamic models

The thermodynamic model of U-tube collector is shown in Fig. 2, in order to facilitate the analysis, based on the thermodynamic method, the thermodynamic model of U-tube all-glass vacuum tube collector is established. E is the fire use of solar radiation. ΔE_{xs} is the fire loss of solar radiation, respectively. E_{Λ} and Q_{Λ} are the fire and heat absorbed by the U-type all-glass vacuum tube solar collector, respectively. E_m and H_m are the fire and energy of the inlet water to the inlet tank of the U-shaped all-glass vacuum tube solar collector, respectively. E_{cwt} and H_{cwt} are the fire and energy of the outlet water of the U-type all-glass vacuum tube solar collector coupling box, respectively. ΔE_t and Q_t are the thermal and thermal energy of the heat lost to the surrounding environment by the U-type full-glass vacuum tube solar collector: E and U are the thermal and internal energy stored in the U-type full-glass vacuum tube solar collector. $\Delta E_{x,e}$ for the U-type all-glass vacuum tube solar collector due to the process of irreversible loss of fire.

The energy balance equation for the U-type all-glass vacuum tube solar collector is as follows:

$$Q_A = AcI\theta = U_\gamma + Q_L + (H_{out} - H_{in}) \tag{1}$$

where A_c is the effective light-gathering area of the vacuum collector tubes of the all-glass vacuum tube solar collector, taking into account the role of diffuse reflective panels, 20 per cent of the scattered light and the different refraction of light at different angles of incidence by the cover glass tubes.

The useful energy output of the glass vacuum tube solar collector per unit time:

$$HU = H_{out} - H_{in} = m_c c_p (T_{out} - T_{in}) \tag{2}$$

where m is the mass flow rate of water in the combined box of glass vacuum tube solar collector, kg/h. c_ρ is the constant pressure specific heat capacity of water, $J/(kg \cdot K)$. T_{in} and T_{our} are the inlet and outlet water temperatures of the combined box of glass vacuum tube solar collector, K.

If the convective heat loss of the gas in the vacuum jacket of the collector is ignored, the heat dissipated by the glass vacuum tube solar collector to the surrounding environment per unit time is:

$$Q_L = Q_{ins} + Q_g = k_{ins} I_{ins}(T_{col} - T_0) + U_L A_g (T_p - T_0) \tag{3}$$

where the heat loss in the vacuum collector tube portion of the collector can be expressed as:

$$U_L A_g (T_p - T_0) = (h_{c-g,l} + h_{c-g,e}) A_g (T_p - T_g) \tag{4}$$

According to the principle of radiant heat transfer, the radiant heat loss of the selective absorption coating of the inner glass tube of the vacuum collector is:

$$Q_r = \frac{\sigma \varepsilon_p}{1 + \frac{\varepsilon_p d_p}{\varepsilon_g d_g}(1 - \varepsilon_g)} A_g (T_p^4 - T_g^4) \tag{5}$$

where ε_p and ε_κ denote the emissivity of the inner glass tube and the cover glass tube, respectively. σ is the Boltzmann constant, and 5.67×10^{-8}.

The thermal efficiency of the glass vacuum tube solar collector at stable operation can be expressed as:

$$\begin{aligned} \eta_i &= \frac{H_i}{Q_i} = \frac{H_i}{Q_i + Q_i} \\ &= \frac{m_c c_p (T_{con} - T_m)}{m_c c_p (T_{con} - T_m) + \left[\frac{1}{\alpha_{con} d_1} + \frac{ln(d_2 / d_1)}{2\lambda_{ion}} + \frac{1}{\alpha_0 d_2}\right] + \left(\frac{1}{h_{g-0}} + \frac{1}{(h_{c-g,t} + h_{c-g,t})}\right)} \end{aligned} \tag{6}$$

The output of the glass vacuum tube solar collector is used for useful fire:

$$E_u = E_{out} - E_{in} = mc\left[(h_{out} - h_{in}) - T_0 (S_{out} - S_{in})\right] \tag{7}$$

Where h_{out} and h_{in} are the enthalpy of water at the inlet and outlet of the glass vacuum tube solar collector header box, and S_{in} and S_{out} are the entropy of water at the inlet and outlet of the glass vacuum tube solar collector header box, respectively.

The fire efficiency of the glass vacuum tube solar collector is:

$$\begin{aligned} \eta_i &= \frac{E_w}{E_s} = \frac{E_{out} - E_{iv}}{E_s} = 1 - \frac{\Delta E_2 + \Delta E_{iv} + \Delta E_{iv}}{E_s} \\ &= 1 - \frac{Q_t\left(1 - \frac{T_0}{T_P}\right) - m_t\left[(h_{out} - h_{out}) - T_0 (S_{out} - S_{out})\right] + Q_t\left[\frac{1}{3}\left(\frac{T_0}{T_S}\right)^4 - \frac{4T_0}{3T_S} + \frac{T_0}{T_P}\right]}{Q_t\left[1 + \frac{1}{3}\left(\frac{T_0}{T_S}\right)^4 - \frac{4T_0}{3T_S}\right]} \end{aligned} \tag{8}$$

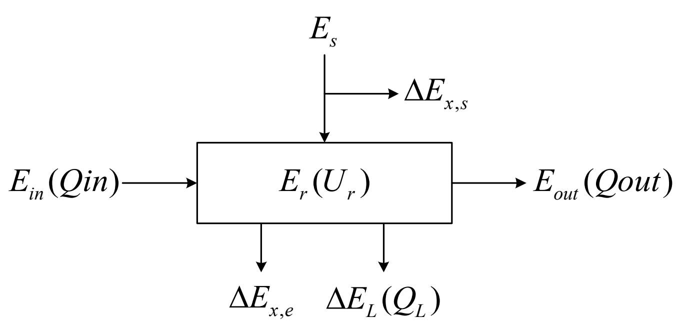


Figure 2: Thermodynamic model of the u-tube collector

III. A. 4) Hot water piping design programme

The low-temperature hot water floor radiant heating system generally adopts a two-pipe system to ensure that the water supply temperature of each group of coils is basically the same. The use of manifolds and collectors connected to the piping, and the setting of heat control metering devices in front of the manifolds, can realise sub-household control - and heat metering and charging. The surface temperature of the floor can be determined by adjusting the average temperature of the supply and return water, the spacing of the coils and the thickness of the buried pipe layer. Low-temperature hot water floor radiant heating water supply temperature is generally 45 ~ 60 ℃, supply and return water temperature difference is generally 5 ~ 10 ℃. Hot water piping design shown in Figure 3.

Low-temperature radiant floor heating system used in the heating coil material selection should be based on the durability requirements, conditions of use, heat medium temperature and working pressure, system water quality requirements, material supply conditions, investment costs and other factors to choose. At present, polybutylene tubing (PB) and cross-linked polyethylene tubing (PEX) are the two types of tubing widely used in this system. In this programme, cross-linked polyethylene pipe (PEX) is chosen to be directly applied to the solar low-temperature radiant floor heating system, taking into account its good heat transfer performance, and reducing the water supply temperature and the collector temperature under the improvement of its operation efficiency.

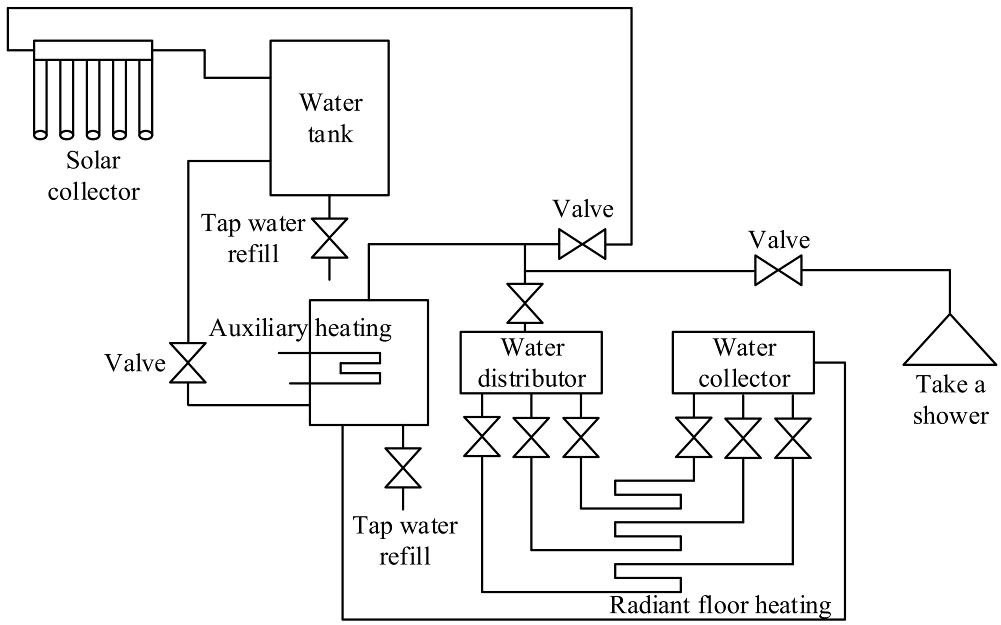


Figure 3: Hot water pipeline design

III. A. 5) Structural design solutions for heating floors

(1) Structure of the floor layer

Because of the low temperature radiant floor heating system water temperature is low, the pipeline is basically not scaling, the main use of pipeline buried in the mat layer at once. Figure 4 for the floor radiant heating structure schematic diagram, Figure 1 ~ 5 were the surface layer, mortar levelling layer, bean stone concrete, insulation layer, floor. Among them, the insulation layer is to ensure that the heat can continue to pass upward, insulation materials should be preferred density of lightweight high-efficiency thermal insulation materials, and in the insulation layer on a layer of thermal insulation layer, set up a layer of waterproofing in the filler layer, the filler layer is generally used in cement mortar.

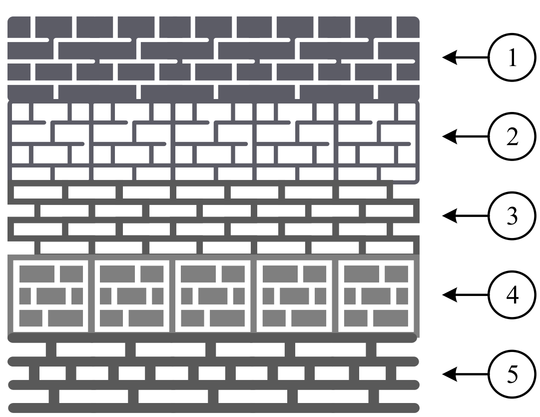


Figure 4: The floor radiation heating structure schematic

(2) Coil laying method

Figure 5 for the six types of coil laying diagram, solar radiant floor heating system coil laying is mainly divided into snake type and back to the type of two kinds of snake-type laying is divided into a single snake-type, double snake-type and staggered double-snake-type laying three kinds of: back to the type of laying is divided into a single type of back to the type of back to the type of back to the type of back to the type of back to the type of back to the type of back to the type of back to the type of back to the type of back to the type of back to the type of laying three kinds of. The main factor affecting the coil laying method is the minimum bending radius of the coil. If the coiler bending radius is too large, the coiler laying method will be limited. And to meet the bending radius at the same time to make the thermal efficiency of solar radiant floor heating to reach the maximum. When laying plastic tubes, the surface temperature field should be made as uniform as possible. According to the return type arrangement, then after the centre of the plate surface of any one profile, high temperature and low temperature tubes are arranged at intervals with each other, it is easy to produce a homogenising effect, this arrangement is more uniform than the other arrangement of the plate surface temperature.

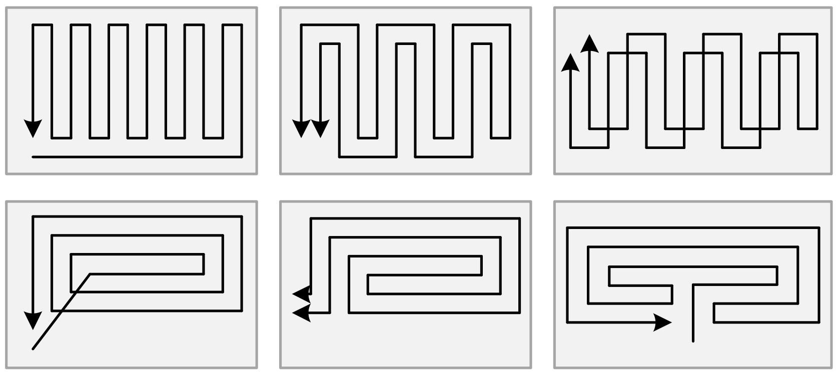


Figure 5: The six kinds of laying of the coil are shown

III. B. Residential rainwater utilisation technology design

According to the relevant norms and requirements of natural resources recycling, rainwater in the project area that can be infiltrated in situ must be considered to be infiltrated in situ, and if it is not possible to realise in situ infiltration, rainwater collection technology needs to be set up to collect and store rainwater for use. Rainwater in the project area is disposed of by infiltration and storage, and the rainwater collection and utilisation technology mainly consists of three parts: setting up recessed green space, setting up permeable paving brick ground, and setting up an integrated system of infiltration and drainage. Detailed descriptions are shown below:

III. B. 1) Installation of recessed green spaces

Residential rainwater use facilities under the concave green space is a natural rainwater infiltration facilities, with the role of strengthening rainwater infiltration, which emphasises the management of urban rainwater from the source, the realization of intra-city consumption of rainwater resources, and the restoration of the natural cycle path of urban water resources. The rainwater storage and infiltration system of concave green space is composed of four elements: green space, building, hardened pavement and drainage system, in which the green space occupies a central position. The top surface of the planting soil in the green space is concave and lower than the peripheral road surface by 100mm, and the elevation of the rainwater outlet in the green space is 50mm higher than the top surface of the planting soil, which can ensure that the surface of the rainwater outlet is higher than the top surface of the planting soil in the green space and lower than the road surface in the peripheral road surface, so that the concave green space can form a rainwater storage volume, which can assume the responsibility of storing and infiltrating rainwater coming from the guest land. When the rainfall exceeds the designed collection capacity in the residential project area, the excess rainfall can be discharged into the municipal rainwater network through the rainwater outlets in the recessed green space.

III. B. 2) Installation of permeable tiled floors

In order to fully reflect the design purpose of rainwater use, the pavements, non-motorised access, paving plaza around the building using permeable ground, car parks using grass tiles on the ground, improving the overall bearing capacity of the permeable ground, to ensure that the normal use of the ground reliability can be effectively avoided during the construction period of the vehicles on the ground caused by the damage. Permeable bedding layer and the surface layer laid between the sand layer, make full use of the composite bedding layer (gravel layer and sand layer, etc.) intercepting pollution, filtration, storage role, to ensure that the reproduction period of rainwater fully infiltration of the ground.

III. B. 3) Installation of integrated exfiltration and drainage systems

The use of an integrated infiltration and drainage system or infiltration pipe can reduce or eliminate the need for a traditional stormwater system. The core of the system approach is to differentiate the slope of the rainwater infiltration pipe between wells from the hydraulic slope of the system drainage, and the infiltration pipe between the intermediate pipeline wells adopts a slope of 1% to 2%, which can quickly discharge impurities and sediments of rainwater into the infiltration inspection wells, and maximise the storage of rainwater in the system in order to ensure that rainwater maximises infiltration into the underground soil and reduces the external discharge of rainwater. Combined with the project situation, it is proposed that the rainwater collection pipeline be set up as an integrated pipeline for infiltration and drainage, and the infiltration check well be set up with a 0.3m sand sedimentation chamber, with the aim of temporarily storing the suspended matter in rainwater in the check well and depositing the suspended matter in the check well through natural sedimentation, so as to facilitate the emptying of the well.

IV. Empirical analysis

IV. A. Analysis of the effect of the application of residential solar heating technology

IV. A. 1) Research sample

A five-story residential building in a city as an example, assuming that the floor area of each floor is 120m², each household has a share of the roof area of 50m², the best angle of inclination of the collector in winter use for the local latitude plus 10 °, we take the collector angle of inclination of 46 °, then the collector area of each household is 30m². At this time, the ratio of the floor area to the area of collector for the ratio of 1: 0.36. In order to facilitate the calculation, we enter into the various floors of the solar pipe insulation so that ignore the heat loss of the pipe is considered to be the same amount of solar radiation received by each layer. In order to facilitate the calculation, we insulate the solar pipes entering into each floor, so that the heat loss of the pipes is ignored and the solar radiation received by each floor is considered to be the same. Therefore, we will analyse the following for single-storey households.

IV. A. 2) Evaluation indicators

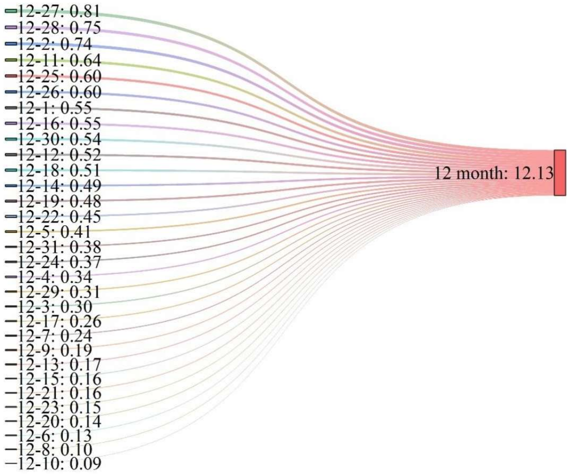
To analyse the effectiveness of the application of residential solar heating technology, the two concepts to be used below are first explained here as energy saving rate and guarantee rate. The details are expressed as follows:

The energy saving rate is the percentage of energy saved using the solar heating system and is calculated as the additional energy consumed in the technology / energy consumed by the conventional heating system. The formula assumes that the additional energy of the technology is the same as the energy used in the conventional heating system, and that the two systems provide the user with an equal amount of heat at the right temperature for a specified period of time.

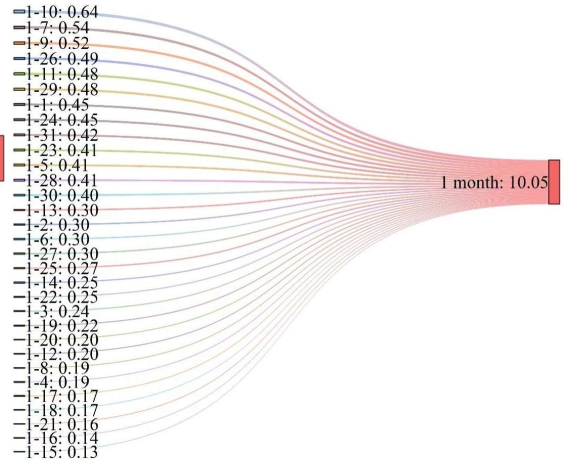
The solar guarantee is the heat provided by the solar part of the technology divided by the total load of the technology.

IV. A. 3) Guarantee rate analysis

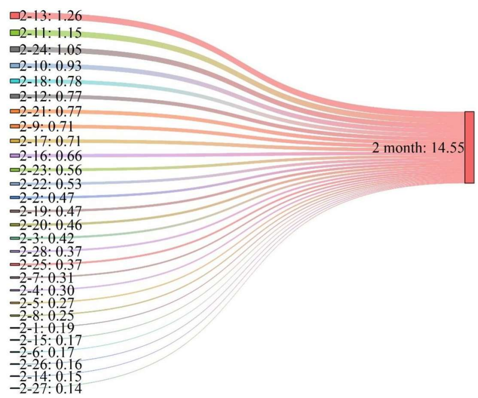
According to the definition of the evaluation index, the effective solar radiation collected by the collector and the daily heating energy consumption can be obtained every day during the heating period, and then the solar energy guarantee rate, as well as the energy saving rate using solar energy can be derived. Figure 6 shows the Mulberry diagram of solar energy guarantee rate, where (a) ~ (c) are December, January and February respectively. Combining Fig. 6 (a)~(c) it can be seen that the solar energy guarantee rate is higher in December (12.13), February (14.55) and lowest in January (10.05), which is caused by the weaker solar radiation in January, the effective radiation received by the solar collector is smaller, while the average daily temperature is lower in January, which requires more energy consumption.The situation is just the opposite for the months of December and February. In addition can also be seen in the monthly solar guarantee rate size sorting relationship, such as the 27th of December, the solar guarantee rate of 0.81, much larger than the other days in December, a more intuitive demonstration of the dynamic trend of the solar guarantee rate in December ~ February, and these three months of the solar guarantee rate of more than 10, fully satisfied with the consumption of natural resources in the residence.



(a)12 month



(b)1 month



(c) 2 month

Figure 6: The kernel of the solar guarantee

IV. A. 4) Analysis of energy saving rates

Table 2 shows the calorific value of the energy and the amount of primary energy converted to it, and Table 3 shows the energy saved by solar heating during the heating period. Combining the data in Table 2 and Table 3, it can be seen that the energy saved by solar heating in one heating period is equivalent to the energy provided by 3236.684 kWh of electricity, 318.9329 Nm³ of natural gas, and 107.6983 Nm³ of liquefied petroleum gas, and the use of solar heating can save 35.23% of the energy consumption for heating in one heating period (8652.301/24559.1414). = 35.23 per cent).

Table 2: Energy calorific value and equivalent energy amount

Energy type	Calorific value/MJ	Reduced energy amount/kg
Coal power(kwh)	3.583	0.119
Natural gas(Nm³)	36.511	1.235
Liquefied gas(Nm³)	104.544	3.685

Table 3: Energy of solar heating in the heating period

Month	11 month	12 month	1 month	2 month	3month	Total
Energy consumption/MJ	919.6724	7743.2607	8678.2345	6147.0074	1070.9666	24559.1415
Save energy/MJ	532.2268	283.4304	3384.2653	3588.9114	863.1961	8652.0301
Equivalent electricity/KWh	147.8387	912.0674	940.0731	996.9254	239.7794	3236.6840
Equivalent gas/Nm³	14.5650	89.8698	92.6356	98.2368	23.6258	318.9329
Liquefied gas/Nm³	4.9211	30.3455	31.2829	33.1685	7.9803	107.6983
Monthly energy efficiency	0.5780	0.4261	0.3879	70.5871	0.8028	72.7818

For a 120m² dwelling, the south wall area is about 50m², and for ease of analysis, we assume that half of the south wall area is set up with collectors. That is, 30m², and the vertical wall inclination angle of 7 °. Still using the above solar collectors, the effective solar radiation received by a single-floor household during a heating period is shown in Table 4. It can be concluded that, when the roof and wall collectors set up to the building heating, a heating period can save heating energy consumption of 57.86% (14209.4101/24559.1415 = 57.86%). The energy saving effect of using solar energy for heating in residential buildings is considerable.

Table 4: The roof and metope all set the solar energy saving rate in the heating period

Month	11 month	12 month	1 month	2 month	3month	Total
Energy consumption/MJ	919.6724	7743.2607	8678.2345	6147.0074	1070.9666	24559.1415
Roof collector heat/MJ	532.2268	283.4304	3384.2653	3588.9114	863.1961	8652.0301
Wall collector heat	247.2435	1535.5998	1545.4448	1750.8952	478.1968	5557.3800
Full heat of the collector	779.4703	1819.0302	4929.7101	5339.8066	1341.3929	14209.4101
Monthly energy efficiency	0.8476	0.2349	0.5681	0.8687	1.2525	0.5786

IV. B. Analysis of the effectiveness of the application of residential rainwater utilisation technologies

IV. B. 1) Rainfall data preparation

(1) Storm intensity formula and Chicago rain pattern

The storm intensity formula is a rainfall calculation formula derived in accordance with certain methods on the basis of analysing and collating data recorded by rain gauges in various places. The existing rainstorm intensity formula takes the form:

$$q = \frac{167A_1(1+C\log P)}{(t+b)^n} \tag{9}$$

where, q - Design storm intensity, $L/s\cdot ha$, P - design return period, a, t - rainfall duration, min, A_1, C, b, n - local parameter, which can be obtained by checking the local storm intensity formula.

The more widely used Chicago rain type is used in the model simulation of this topic to allocate the rainfall intensity in time. The basic formula for the Chicago rain pattern is:

When $0 \le t_b \le rr$, i.e:

$$i(t_b) = \frac{(1-n)\times r^{''}\times a}{\left(t_b - t + r\times b\right)^n} + \frac{n\times b\times r^{''+1}\times a}{\left(t_b - t + r\times b\right)^{n+1}} \tag{10}$$

When $rt < t_a \le t$, i.e:

$$i(t_a) = \frac{(1-n)\times(1-r)^{''}\times a}{\left[t - t_a + (1+r)\times b\right]^p} + \frac{n\times b\times(1-r)^{''+1}\times a}{\left[t - t_a + (1-r)\times b\right]^{p+1}} \tag{11}$$

where $a = 167A_i(1+C\log P), b, n, A_i, p$ has the same meaning as in the formula for storm intensity, r - rainfall peak coefficient, i.e., the ratio of the time from the moment of rainfall onset to the moment of rainfall peak to the entire rainfall calendar time, which is taken as 0.2 in the model, t - Total rainfall calendar time, t_b - Pre-peak rainfall calendar time, t_a - Post-peak rainfall duration.

When the parameter b, n, A_1, P, r is determined, take the time interval t_b and t_a can be obtained rainfall intensity in the time scale of the distribution process, that is, the Chicago rainfall process line.

(2) Design of rainfall data

According to the storm intensity formula, the Chicago rainfall process line is used to obtain the time scale distribution of 2h rainfall total under the seven return periods of 0.2a, 0.4a, 0.6a, 0.8a, 1a, 3a and 9a. The storm intensity equation is shown in equation (12), and the rain peak coefficient r in the model takes the value of 0.2. i.e:

$$q=\frac{2001(1+0.811\lg P)}{(t+8)^{0.711}}(P=0.25\sim 10a)(3.4) \tag{12}$$

where, q - Average storm intensity over the rainfall calendar time, $L/s\cdot ha$, t - Rainfall calendar time, min, P - rainfall recurrence period, a.

Calculation of 2h rainfall under seven different recurrence periods using the storm intensity formula is shown in Table 5. According to equation (9) and equation (12) can be obtained:

$$a=2001\times(1+0.811\log P), C=0.802, b=8, n=0.705, r=0.2 \tag{13}$$

Table 5: Rainfall of 2h in seven different recurring periods

Rainfall recurrence period	0.2a	0.4a	0.6a	0.8a	1a	3a	9a
2h Rainfall amount(mm)	22.75	33.79	44.88	55.95	62.72	70.34	81.92

Bringing the above values into the public (10) and equation (11), the rainfall distribution equation can be derived as follows:

When $0\le t_b<48$, i.e:

$$i(t_b)=\frac{a\times(8.899-0.151t_b)}{(51.2-t_b)^{1.711}} \tag{14}$$

When $48\le t_a\le 120$:

$$i(t_a)=a\times\left[\frac{0.201}{(t_a-36.8)^{0.711}}+\frac{2.373}{(t_a-43.2)^{1.711}}\right] \tag{15}$$

Taking the time step of 10min, the rainfall process volume data allocation for 2h rainfall under seven different rainfall recurrence periods that can be calculated by using the Chicago rainfall process equation (14) and equation (15), the time course allocation of 2h rainfall under seven different rainfall recurrence periods is shown in Fig. 7. It can be seen that under different rainfall recurrence periods, the rainfall intensity increases with increasing rainfall duration before the rainfall event proceeds to 50 min, and decreases with increasing rainfall duration after the rainfall event proceeds to 50 min. The rainfall intensity reached its maximum for all seven return periods from the start of the rainfall event to the time when the rainfall event lasted for 50 min. The maximum rainfall intensity is 122.16mm/min for a return period of 0.2a, and the others are the same, which succinctly illustrates the temporal distribution of the 2h rainfall under the seven different rainfall return periods.

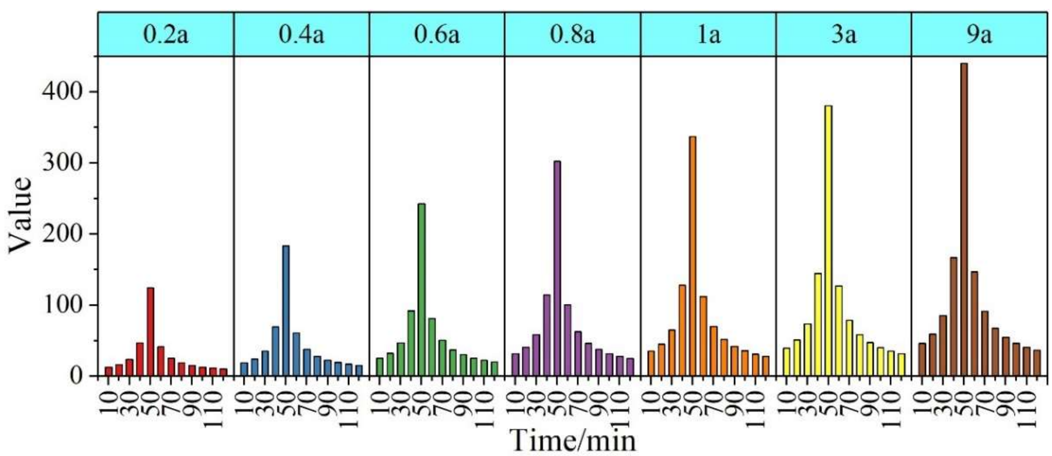


Figure 7: The time range allocation of 2h rainfall

IV. B. 2) Analysis of results

The simulation analysis software was used to simulate the runoff process at each outlet section under the rainfall return period of 0.2a, 0.4a, 0.6a, 0.8a, 1a, 3a and 9a. The simulation results of the peak flow, peak moment and runoff coefficient of each outlet section in the residence using this technology and not using this technology are shown in Table 6, in which the catchment areas of outlets #1, #2 and #3 are 60hm², 12hm² and 10hm², respectively. It can be seen that the peak moment of the stormwater pipe outlet using the technology and not using the technology is delayed compared to the time of the maximum rainfall intensity, this is because part of the initial rainfall will be infiltrated, and surface depressions will also store some rainwater, and therefore did not immediately form surface runoff, which leads to surface runoff generation time and the time of the time of the rainfall time difference. Therefore the peak moment at the outlet of the stormwater pipe lags behind the moment of maximum rainfall intensity. For the runoff coefficients, there was a reduction in the runoff coefficients with the technique compared to without the technique for different rainfall return periods. For a rainfall return period of 0.2a, the runoff coefficient was reduced by 0.171 (0.357-0.186=0.171) with a percentage reduction of 47.90% (0.171/0.357=47.90%), and similarly for the others. It can be obtained that the percentage reduction in residential runoff coefficient with the use of the technique in residential houses compared to that without the use of the technique tends to decrease as the rainfall return period increases for different rainfall return periods, i.e., there is a negative correlation between the rainfall return period and the percentage reduction in the runoff coefficient. This result shows that the effect of using the technology on the runoff coefficient is weaker the larger the rainfall return period is compared to not using the technology. The smaller the rainfall return period, the stronger the effect of the technique on the runoff coefficient, which fully confirms that the technique has a good retention and reduction of rainfall runoff from houses.

Table 6: The use of residential rainwater technology

Name		Water outlet	Rainfall recurrence period						
			0.2a	0.4a	0.6a	0.8a	1.0a	3.0a	9.0a
Unused	Peak flow (m³/s)	1#	0.244	0.312	0.357	0.405	0.477	0.564	0.608
		2#	0.427	0.504	0.595	0.696	0.726	0.807	0.94
		3#	0.435	0.55	0.613	0.716	0.788	0.831	0.967
	Peak time	1#	0:47	0:46	0:46	0:46	0:46	0:45	0:45
		2#	1:12	1:12	1:11	1:11	1:13	1:13	1:12
		3#	1:23	1:22	1:21	1:23	1:23	1:24	1:23
	Runoff coefficient		0.357	0.414	0.475	0.537	0.608	0.676	0.726
Use	Peak flow (m³/s)	1#	0.113	0.143	0.162	0.171	0.188	0.221	0.219
		2#	0.278	0.307	0.367	0.406	0.38	0.379	0.408
		3#	0.282	0.348	0.38	0.424	0.419	0.401	0.433
	Peak time	1#	0:52	0:51	0:51	0:51	0:51	0:51	0:50
		2#	1:15	1:15	1:15	1:14	1:14	1:15	1:15
		3#	1:28	1:28	1:27	1:27	1:27	1:26	1:26
	Runoff coefficient		0.186	0.228	0.279	0.336	0.408	0.449	0.494

V. Conclusion

The design method of traditional housing is relatively simple, lacking infrastructure design and construction, with serious energy consumption and low utilisation of resources, which brings certain difficulties to the development of housing construction. To address this problem, this project proposes residential solar heating technology and residential rainwater utilisation technology based on resource recycling technology and symbiotic design concept. Combined with the corresponding research data, the application effect of the proposed two technologies is analysed. The results of this research are presented as follows:

(1) In the analysis of the application effect of residential solar heating technology, the solar energy guarantee rate is the highest in February (14.55), followed by December (12.13), and the lowest is January (10.05), and the technology can save 57.86% of the heating energy consumption, which indicates that the use of this technology for residential heating has considerable energy-saving effect and is perfectly in line with the principle of recycling of natural resources. (2) With the return of rainfall, the energy consumption of heating is reduced by 57.86%.

(2) As the rainfall return period increases, the technology has a smaller effect on the reduction of runoff coefficient, although it decreases from 47.90% to 31.96%, but it is within the permissible range, which greatly indicates that the technology has a very good retention and reduction of rainfall runoff from the residence. This technology can not only stagnate rainwater, reduce rainwater runoff, lower the runoff coefficient, and replenish groundwater resources, but also increase the green area and save land resources, which is of great significance in promoting the sustainable development of natural resources.

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