Renewable Energy Technologies Applied in Architecture and Its Innovative Research

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Abstract. Solar energy and low-temperature geothermal energy are important forms of utilization in renewable energy systems. This article introduces and analyses solar energy systems and heat pump systems, and summarizes its characteristics. And then aiming at the current problems of traditional architectural design processes and their major problems in traditional architectural design processes, we propose a more complete, integrated and renewable energy system design process, which includes architectural design, energy design, construction design, performance evaluation, and provide a reference for the integration of renewable energy technologies and architectural design.

1. Introduction
The rapid economic development and rapidly increasing population are making traditional energy sources gradually depleted. Under the situation of such a severe energy, the building industry with large scale of energy-consuming has present a challenge to the use of new energy. Meanwhile, people's pursuit of quality of life is also increasing, the daily energy consumption of air conditioners, hot water, etc. accounts for an increasing proportion of building energy consumption. Efficient use of renewable energy can ease the exhaustion of traditional energy sources, and meet the rapid development needs of the construction industry simultaneously.

2. Major architecture renewable energy technologies

2.1. Solar utilization technology
At present, the utilization of solar energy by humans mainly focuses on three modes of utilization: photoelectric conversion, photothermal conversion, and photochemical conversion. The most widely used in the field of architecture is solar thermal energy utilization technology, mainly including passive solar energy utilization technology, solar heating technology and solar energy cooking technology

2.1.1. Passive solar energy utilization technology. Passive solar energy utilization technologies mainly include passive solar houses and solar ventilation cooling technologies. Passive solar houses do not require equipment and components such as collectors, heat exchangers, and water pumps, but intelligently deal with the external body and interior space by rationalizing the orientation of the building and its positional relationship with the surrounding environment. Choose the right building materials and structures, to enable buildings to collect and store solar radiant heat in the cold season and maintain a certain heating temperature in the room. Therefore, passive solar houses have the advantages of simple structure, low cost, convenient maintenance and management, etc., but it also
has the disadvantages of poor indoor comfort, high temperature fluctuations, and the need to use auxiliary heat sources when sunlight is not available.

Solar ventilation cooling technology is to take use of natural hot air pressure ventilation, to strengthen the chimney effect through solar radiation, so that provide power for air flow, and as a result, indoor ventilation is increased and ventilation effect is improved, so as to achieve the purpose of ventilation, dehumidification, cooling and removal of harmful gases. Solar ventilation cooling technology is an effective way to use solar energy, without requirement for increasing any equipment investment. It can make full use of the inherent characteristics of the sun itself and realize the rational use of solar energy sources.

2.1.2. Solar water heating technology. Solar water heating system as an energy-saving system using clean energy, is a solar energy utilization technology with high photo-thermal conversion efficiency and wide application. The solar water heating system is mainly composed of three parts: a solar collector, a heat storage device and a circulation loop. Some systems also have an auxiliary heating device. According to the way of operation, solar hot water system can be divided into natural circulation heat collection, forced circulation heat collection and constant temperature water drainage and heat collection system.

The working principle of natural circulation heat collection system is shown in Figure 1. Firstly, the cold water enters the hot water storage tank through the cold water system until the set water level is reached. Secondly, the low-temperature water in the tank enters the collector through the lower circulation pipe, and the heater is heated by solar radiation to increase water temperature. Due to the difference in the proportion of hot and cold water, the Thermal siphon pressure is produced to make the hot water flow from the lower end of the collector to the upper end, and then go through the upper circulation pipe to the storage tank. Since the system is based on thermosyphon action to achieve hot water circulation, without any external force, so it is called natural circulation heat collection system.

![Figure 1. Natural circulation heat collection system](image)

Compared with natural circulation system, forced circulation heat collection system can obtain higher water temperature, without location restrictions. But it also has some drawbacks, for example, it requires the use of electricity, the maintenance of this system is complicated and the control device is easily damaged. This type of system is mainly used for large hot water systems or where water temperature requirements are high.

2.1.3. Solar energy cooking technology. Solar cooker is a solar energy utilization device that obtains solar radiation energy through heat collection, heat transfer and heat storage, which can be used for boiling water or cooking. Its power size depends on user needs. The power of general household solar cooker is in the range of 500 ~ 1500W, illumination area about 1~3m². According to the different
ways of heat collection, the solar cooker can be divided into concentrating solar cooker, box solar cooker, and integrated solar cooker.

2.2. Geothermal utilization technology
Geothermal energy is the heat contained in the rocks and fluids below the surface. Through technique acquisition, it can be used to generate electricity for heating or cooling to buildings. However, as shallow geothermal resources are low-grade energy, it must enhance its energy taste through heat pump technology while applied in architecture. From the system application, the shallow geothermal air conditioning system can be divided into ground source heat pump system, surface water source heat pump system and underground water source heat pump system.

2.2.1. Soil source heat pump technology. According to underground heat exchanger buried pipe form, soil source heat pump technology can be divided into horizontal buried ground source heat pump system and vertically buried ground source heat pump system. The former is characterized by low cost, but shallow soil temperature is susceptible to changes in outdoor weather conditions; while the latter has the characteristics of small area and stable working performance, so it is more widely used.

Soil source heat pump system has the following features:
- Geothermal temperature amplitude is small and relatively stable, especially the rock and soil below 10m.
- Rock and soil have good regenerative properties itself.
- Compared with Air source heat pump, it can save 10%~20% of the defrosting energy consumption.
- After long term continuous operation of the system, it is easy to cause the accumulation of cold and heat of underground rock and soil, and affect the water temperature of the buried pipe.
- The thermal properties and heat transfer performance of different types of geotechnical materials are quite different.
- Soil source heat pump system is expensive.

Moreover, in the design and operation of the ground-source heat pump system, care should be taken to keep the cumulative heat released from the summer to the ground approximately equal to the cumulative heat absorbed from the ground during the winter, otherwise it will reduce the heat transfer performance of the ground heat exchanger, or even disable it.

2.2.2. Surface Water Source Heat Pump Technology. Surface water source heat pump system is a system that uses surface water bodies such as rivers, lakes, seawater, or source biological water sources as heat source of heat pump units. The system is mainly suitable for situations where there is sufficient surface water body available near the building, where the heat in the water body is transferred to the heat pump unit by the distribution system.

According to different cold source side transmission and distribution system structure, it can be divided into closed surface water source heat pump systems and open surface water source heat pump systems.

Surface water source heat pump system has the following features:
- The temperature of surface water is larger than that of underground water or underground rock, changing along with the season and the depth of the water body.
- The cost of the ground water source heat pump system is relatively low.
- Due to surface water quality problems, care should be taken to prevent open system corrosion and algae problems.
- Surface water temperature will decrease in winter, so the operation of the surface water source heat pump system in winter needs to be guarded against freezing.

2.2.3. Groundwater source heat pump technology. Groundwater source heat pump systems are generally used in areas where groundwater resources are abundant and allow exploitation.
According to different groundwater use way, groundwater source heat pump system can be divided into direct use system and indirect use system, as shown in Figure 2.

![Groundwater source heat pump systems](image)

Figure 2. Groundwater source heat pump systems

Groundwater source heat pump system has the following characteristics:

- Groundwater source heat pump system has significant energy saving effect.
- The economic performance of underground water source heat pump is good.
- Recharging effect is very important for the use of groundwater source heat pump systems.

### 3. Optimized design of renewable energy technology in construction

**3.1. Integration design process**

Integration design of building renewable energy system is to make an organic combination of architectural design and renewable energy systems. Starting from renewable energy technologies, we analyse the impact of them, and then determine how it is shown in the architectural design process, as shown in Table 1.

| Renewable energy technologies | Influencing factors | Integrated design |
|-------------------------------|---------------------|-------------------|
| Solar energy utilization technology | Solar collector system type; collectible area; equipment efficiency | Site selection; architectural design; layout; photothermal, photoelectric system design |
| Geothermal energy utilization technology | Hydrogeology; room location and size; terminal device | Site selection; architectural design; layout; ground source heat pump system design |
| Biomass energy utilization technology | Total waste; equipment performance; emissions indicators | Site planning; garbage station location; biomass energy system design |

According to the influence factors of renewable energy utilization technology and how it is reflected in architectural design, the building renewable energy integration design process combines
architectural design with renewable energy system design. The process contains architectural scheme design, energy design, construction design and performance evaluation.

3.2. Architectural scheme design
The design stage of the building renewable energy system integration design process also includes two parts: site planning and monomer design. In site planning, in addition to meeting the requirements of the functional design and space design of the site in the traditional architectural design process, it is also necessary to meet the design of renewable energy. In monomer design, in addition to meeting the requirements of traditional architectural design processes such as building materials, building entrances, building functions, etc., it also needs to meet the requirements of renewable energy systems.

3.2.1. Site planning. Site planning requires software simulation of building orientation, building spacing, and building height in selected projects, to determine the area covered by the building and its location. And then, simulate the best position and best inclination of solar collector board, as well as wind energy utilization system location, room location and size, tank location, etc.

In particular, in order to make full use of solar energy, the site on the south with hillsides or thick trees should not be chosen. To prevent sunlight from being blocked during the winter, while in shading and heat insulation in summer, planting deciduous plants is a relatively good decision. For mountain architecture, it should be located on the slope to the sun as far as possible, and meanwhile properly adjust slope by digging fill to facilitate receiving sunlight.

3.2.2. Monomer design. Monomer design promotes simultaneous design of architectural design and renewable energy systems. From the perspective of combination method, it can be divided into three kinds of design: integration with building roof, integration with wall and integration with building components.

a) Integration with building roof
The roof can be more fully greeted with sunlight, therefore, to maximize the use of solar energy, the roof is the best choice for arranging solar collector plates or photovoltaic panels. Secondly, from the aesthetic point of view, under normal circumstances, a man’s sight is generally inaccessible to the roof, so it eliminates the influence of solar equipment on the appearance of the building to a large extent. In addition, the roof space of the building is relatively difficult to use, solar equipment installed by vertical traffic to the roof, and it makes the routine maintenance of solar energy equipment simple. The good ventilation on the roof is also conducive to the safe and stable operation of solar energy equipment.

b) Integration with wall
The external surface of buildings as the largest contact area with the sun is the best choice for the installation of solar installations. Therefore, solar collector panels can be combined with wall design, so that the entire wall is solar collector panels, or take it as a decorative component of the wall, to make the wall a different landscape. In addition, a centralized continuous collector or photovoltaic panel is used to create a strong rhythm in the vertical direction of the whole building, to endow the modern elements of architecture with various elements, so it is no longer a rigid reinforced concrete wall.

c) Integration with building components
Common building components include balconies, windows, sun shading components, etc. The balcony railing and window run through the facade of the building, so it often congregates the focus of sight. From another aspect, this also makes them an important part of the integration of solar technology and architecture. Therefore, installing solar skin devices at windows and balconies, to make it an important factor in the consideration of the architectural design, may be a design method worthy of reference.
3.3. Energy design.
Energy design is a missing part of the traditional architectural design process, but it is a particularly important part of the design process for building renewable energy systems. Energy design includes the use of design software, equipment selection, parameter setting, area calculation, auxiliary heat source selection and auxiliary heat source calculation.

3.3.1. Software-based design. Utilize the current renewable energy system design software to analyse the construction demand for building water consumption and electricity consumption, and then perform simulation analysis of heat collection efficiency, heat transfer capacity, loss rate, inclination, etc.

3.3.2. Equipment selection. Equipment selection includes selection of energy storage equipment, water storage equipment, water heater type and air conditioning type.

3.3.3. Parameter setting. Parameter setting is to calculate the water consumption, power consumption, heat collection efficiency, heat exchange capacity, loss rate, and inclination of the selected equipment, and set the working time and outlet temperature of the equipment.

3.3.4. Area calculation. Area calculation is to determine the area that can be used for collecting heat through the architectural design derived from the architectural design, and set the tank volume, determine the buried pipe method, and set the depth of the buried pipe according to the population and its water demand.

3.3.5. Auxiliary heat source selection. The role of the auxiliary heat source of the solar hot water system is to assist in the production of hot water when the capacity of solar energy to produce hot water does not meet the requirements for use. Auxiliary heat source should be selected based on economic input, fuel pollution, etc.

3.4. Construction design
Construction design is based on the construction materials, construction size and other construction requirements, to draw a construction plan to meet the construction requirements. Construction design mainly includes architectural design details, auxiliary space design, structural design, fitting design, construction cost budget, etc. The architectural design details include the balcony awning nodes details, wall nodes details, roof construction node details etc., after joining the renewable energy system. Auxiliary space design refers to how the building auxiliary space including storage spaces, entrances, walkways, balconies, etc., is combined with renewable energy sources. Structural design includes the impact of renewable energy systems on the calculation of structural bearing capacity. Project construction cost budget includes the impact of renewable energy system on project construction budget.

3.5. Performance evaluation
The performance evaluation of the building's renewable energy system design process includes project investment payback period, renewable energy system energy saving rate, emission reduction, and comprehensive working condition evaluation.

The payback period means that the renewable energy system controls the cost of the project after considering the initial investment, maintenance costs, operating costs, policy subsidies, etc. of the renewable energy in the actual construction and operation of the building and uses the minimum cost. Get the most economic benefits. Energy-saving rate refers to how much energy is saved compared to conventional systems after using a renewable energy system. Emission reduction and comprehensive working conditions evaluation refer to the evaluation of the safety of building structures and the use of building functions after the accession of renewable energy systems.
4. Conclusion
This paper studies the optimal design of building renewable energy utilization system. Firstly, three kinds of major architecture renewable energy technologies are introduced, mainly including their technical features and application scenarios. Secondly, we propose the optimized design method of renewable energy technology in construction, which is based on the traditional architectural design process, consisting of architectural scheme design, energy design, construction design and performance evaluation. It is concluded that integrated renewable energy system design process could maximizes economic benefits and energy efficiency. The integrated renewable energy design process provides new design steps for building design, and reflect the organic combination of architectural design and renewable energy system design, so it is a new design method of innovation.

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